

NASA Contractor Report 156843

(NASA-CR-156843) MEAN GRAVITY ANOMALIES AND
SEA SURFACE HEIGHTS DERIVED FROM GEOS-3

N79-12630

ALTIMETER DATA Final Report (Ohio State
Univ. Research Foundation) 121 p HC A06/MF

Unclas

A01

CSCL 08E G3/46

38017

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Richard H. Rapp

October 1978



National Aeronautics and
Space Administration

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Acknowledgment

A number of persons have contributed directly or indirectly to the work described in this report. Ray Stanley and Cliff Leitao provided comments that helped develop some of the editing criteria used in the analysis of the altimeter data. Richard Anderle, NSWC, provided the Schwiderski tidal model on tape; Jim Marsh, NASA, provided the detailed geoids in the calibration area; Richard Brown provided cards containing information enabling cross-over locations to be determined.

At Ohio State the extensive programming support that made this work possible was carried out by Mr. Edward Herbrechtsmeier, a graduate student in Geodetic Science. Mr. K. Katsambalos, also a graduate student, provided additional help in a number of ways. Dr. William Kearsley and Dr. Lars Sjöberg made significant contributions to the utilization of this data. Mr. Melvin Schultz, while a graduate student, helped develop our cross-over analysis program and aided in the editing of the data. Reiner Rummel, who is no longer at Ohio State, having returned to Germany in 1976, provided a number of basic ideas that were implemented in our altimeter analysis.

This work has been supported through NASA, Wallops Flight Center, Wallops Island, Virginia, under Contract No. NAS 6-2484 with The Ohio State University Research Foundation.

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Introduction

This report describes the estimation of mean gravity anomalies from Geos-3 altimeter data. The work itself extended from April 15, 1974 to December 31, 1977. The main effort was concentrated in the last eighteen months when sufficient data became available for large scale computations to be carried out.

This specific report describes results obtained to fulfill the given NASA contract written in response to a proposal made by the author. A number of other reports have been prepared related to the altimeter data analysis. These will be referenced in the text of this report.

The Altimeter Data

All data used for this study was transmitted to us on magnetic tape by the Wallops Flight Center. Originally, we received some data in the BCD mode (Leitao, Purdy and Brooks, 1975), but later this data was discarded in favor of data distributed to us in the binary mode (Ibid.). The data that we received in binary form was read using a slightly modified version of the "Caltor" program (Leitao et. al., 1975, revised 1976), Serelis (1975, revised 1976). For our specific purposes we created from the original tapes a BCD type of tape but with certain additional information that was to be used for editing purposes. We should note here that the BCD format contains information that represents averages in a certain time interval. This average represents a "frame" value where the time extent of a frame depends on the data rate used in the data transmissions. In the low data rate the frame length is 2.048 seconds while in the high data rate the frame length is 3.277 seconds. In the low data rate frame there are 20 observations while in the high data rate there are either 32 observations (mode 2) or 320 observations (mode 3).

The additional information obtained from the binary tapes was as follows:

1. The Calculated Averaged Automatic Gain Control Voltage (AGC) for the frame. This value is given on the Wallops binary tape.
2. The square root of the variance of the AGC voltage within the frame as determined from the individual AGC voltage measurements within the frame.
3. The Radar Altimeter Average Attitude/Specular Gate voltage which was given on the Wallops binary tape.
4. The $H_{1/3}$ value which is a measure of sea state. This value is computed for a frame and is given on the Wallops tape (see revisions dated 3/3/76 of the Leitao et al. report).

We should note here that the altimeter data was taken in a global mode and in an intensive mode, the latter being the more accurate. For our studies we used only the intensive mode data.

For a more detailed explanation of the tapes created by us, see the report by Herbrechtsmeier (1977).

Altimeter Data Editing

The actual data type that we are interested in was the separation between the reference ellipsoid and the sea surface. This quantity, referred to as "Sea Surface Height", is computed as follows:

$$(1) \quad \text{SSH} = h - (A - R + b)$$

where

SSH is the sea surface height given with respect to a specified ellipsoid;

h is the height of the altimeter above the reference ellipsoid as determined from the "known" portion of the satellite;

A is the altimeter measurement;

R is the refraction correction;

b is the a priori altimeter bias, if any.

If the sea surface and the geoid would coincide, SSH would be the geoid height which is of specific interest to us.

Errors in the sea surface height as computed from (1) could occur if the altimeter measurement was incorrect, the orbit of the satellite was in error or the altimeter bias was not known. To edit out bad data we initially made plots of the sea surface heights in comparison with the approximately known geoid undulations over the corresponding arc segment. Visual comparisons enabled the identification of potentially bad data. However, it became readily apparent that such a visual process could not be effectively done because of the large amounts of data being received. Consequently, we developed an automatic editing process using criteria found reasonable in the visual editing process, and from comments made about the data by Wallops personnel.

For a frame measurement to be accepted for further processing, it must meet the following criteria:

1. $0.25 < \sigma_{ALT} < 8.00$ meters where σ_{ALT} is the "Altitude Measurement Standard Deviation" given on the binary tape;
2. The absolute value of the sea surface height should be less than 170 meters;
3. The Automatic Gain Control Voltage should lie within the following range: $-78 < AGC < -62$ dbm;
4. The square root of the variance of the AGCV should be less than 2 dbm;
5. The Average Attitude/Specular Gate voltage should be within the following range: $35 < AASG < 999$ dbm;
6. The $H_{1/3}$ value (sea state measure) should be less than 88 meters.

Criterion one was established to delete too noisy or too smooth data. Criterion two was used to delete data that could be off because of very bad orbits. Criterion three checked to see if the AGC voltage fell within normal limits while criterion four examines the variation of the AGCV within the frame. Criterion five was used to detect data taken over land, ice, etc. (Miller, 1977, p. 15). Criterion six was used to see if convergence had been reached in the iterative computation of the sea surface height. If it had not been, we felt the data was poor and should be rejected.

Clearly, the above criteria are somewhat arbitrary. However, they appear to be able to detect most, but not all, of the bad data. A more extensive editing discussion may be found in Herbrechtsmeier (1977).

All the intensive mode data received by us was processed through the data editing program. The original number of frame averages that we started with was 469,800. Of this number 52,111 were deleted by the automatic editing process. We give in Table 1 information related to the number of measurements deleted by one or more of the edit criteria previously described. The i th diagonal elements in this table indicates the number of measurements that have been rejected because the i th criterion and possibly one or more of the other criteria have been met. The off diagonal ij elements in the table indicate the number rejected because the i and j criteria have been met together. The numbers listed in the "independent" column indicate the measurements neglected because only the i th criterion had been met.

Table 1

Data Rejection by Criteria
(see text for explanation)

Criteria No.	1	2	3	4	5	6	Independent
1	<u>7455</u>	1214	1489	2883	3141	2974	1888
2		<u>7079</u>	1890	3980	4828	2083	412
3			<u>14145</u>	3835	8950	3408	3614
4				<u>20102</u>	12539	4578	4483
5					<u>30432</u>	8951	6059
6						<u>18673</u>	6474

In some cases, short one or two data point gaps existed in the data. In this case, a simple linear interpolation was used to fill in the gaps. In this way 9,704 interpolated sea surface heights were generated.

After this analysis it was discovered that certain longitudes were in error (see letter dated November 8, 1977 from H. Ray Stanley). To eliminate this error (it was found some months before the November 8 letter) all data was gone through by hand so that the longitude error and other small errors not detected by the automatic edit process could be found. In this process an additional 5,559 measurements were deleted, leaving a total of 421,834 measurements distributed in 2003 arc segments. The distribution of these arcs is shown in Figure 1.

As a last edit, the new data set was examined to find adjacent values that differed by more than 3 meters. If such unexpected variations were found, they were deleted. A total of 2,540 measurements were so deleted, leaving a final data set of 1976 arcs containing 419,294 "frame" observations.

The Ocean Tide Model

The sea surface height should be corrected for the ocean tide at the time of measurement. The binary tapes supplied by the Wallops Flight Center gave, for each frame average, the ocean tide associated with the Hendershott (1972) tidal model. The specific implementation of this spherical harmonic model (to degree 9) is described by Goodman (1975, p. 4 - 14).

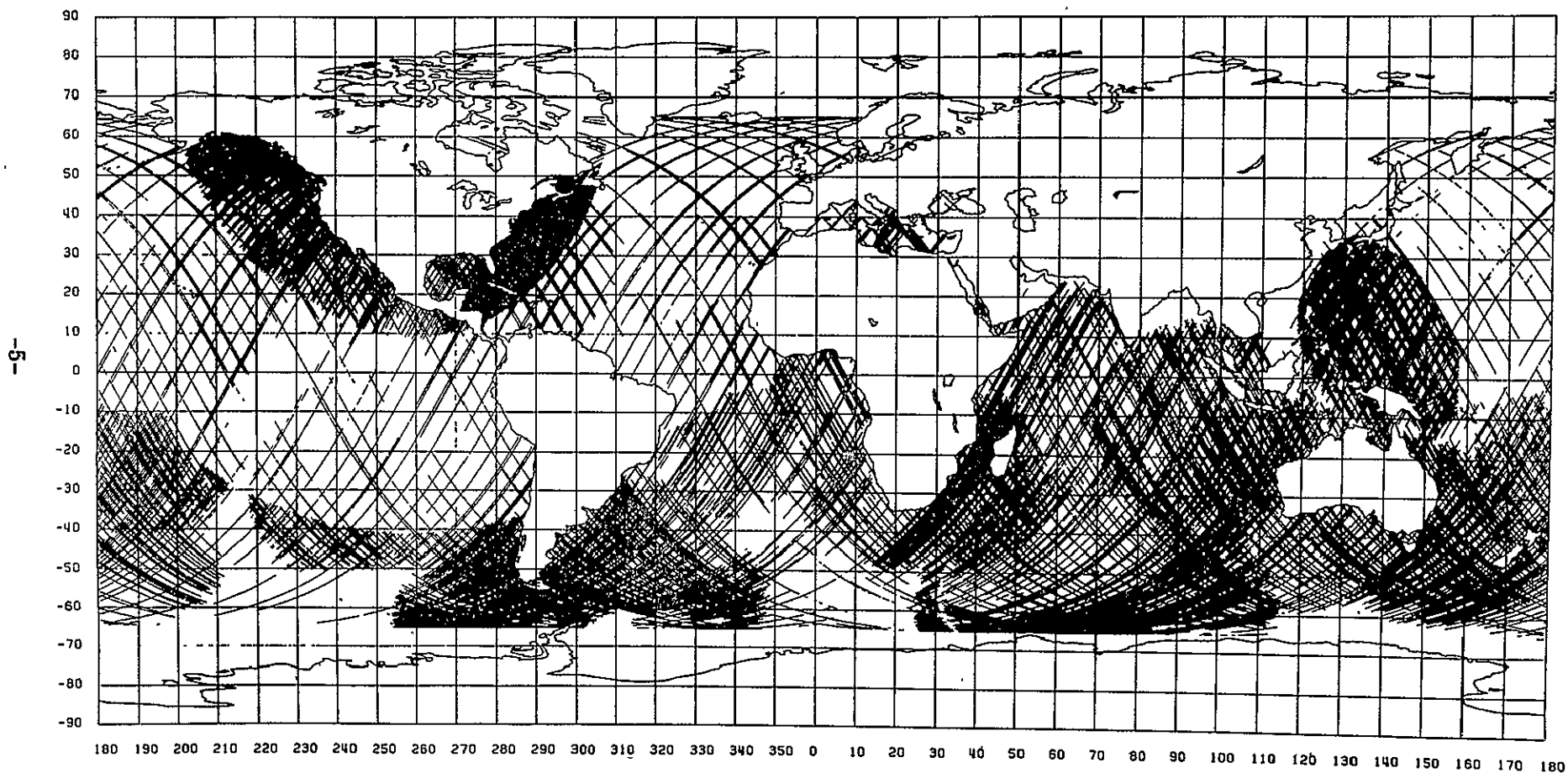


Figure 1

Distribution of Arcs Selected After Editing

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Recently, a more detailed M_2 tidal model was developed by Schwiderski (1977). Tests made by Schwiderski indicate that his model gives better fit to real world data than the Hendershott (1972) model. This newer model is defined by a set of amplitudes and phases for each $1^\circ \times 1^\circ$ block on the earth's surface. Given a specific location and time, the M_2 ocean tide can be obtained through fairly simple formulas after appropriate interpolations are carried out.

Tidal values for the Schwiderski model were compared with approximately 4300 Hendershott values already given on the altimeter data records. In some cases the agreement was good between the models, but differences up to 1.2 meters were found. We consequently decided to compute and use the Schwiderski tide value at all altimeter "frame" data points that had survived our edit process.

Bias Removal and Models

The edited values of the sea surface heights now available are still subject to errors caused by an altimeter bias and orbit error.

The altimeter bias has been discussed by Martin and Butler (1977). In their study they estimated that the intensive mode bias (measured minus true) was -5.3 ± 0.21 m. Although we could have adopted this as constant for all our data, we chose to solve for the bias and orbit error because of the success of our initial efforts (Rummel and Rapp, 1977) in this area.

The orbit error arises from a number of sources including gravity field error, etc. The orbits used for the Geos-3 data were classified by the Wallops Flight Center as to their accuracy as shown in Table 2.

Table 2
Accuracy Classification of Geos-3 Orbits Used in
the Reduction of the Altimeter Data

Code	Source	Quality	Orbit Type
A	WFC	10 M + RMS	1 DAY ARC
D	WFC	3-10 M + RMS	1-8 REV ARC
G	NSWC	5 M + RMS	3 DAY ARC
J	NSWC	3 M + RMS	3 REV ARC
N	GSFC	1-2 M + RMS	5 DAY ARC

WFC = Wallops Flight Center
NSWC = Naval Surface Weapons Center
GSFC = Goddard Space Flight Center

The majority of the orbits computed in the early period of the satellites were from WFC and were of code A. From September 1975 through May of 1976 the orbits were of code J; from May through early June 1976 the orbits were code N with the remaining orbits code G. It was thus clear that we had a diverse set of orbits to work with and that the selection of an approximate error model for the bias and radial orbit error would be very important.

Another possible source of error in the determination of the sea surface heights were the parameters of the reference ellipsoid. (The values used as a reference by the Wallops Flight Center were 6378145 meters for the equatorial radius and 1/298.255 for the flattening.) For most gravimetric geodesy problems, it is desirable to have quantities (such as geoid undulations) referred to a mean or general terrestrial ellipsoid (Heiskanen and Moritz, 1967, p. 214). With respect to such an ellipsoid, the global average geoid undulation would be zero. Since the adopted ellipsoid parameters may not refer to the general terrestrial ellipsoid it is desirable to use a procedure that will yield the sea surface heights with respect to the general terrestrial ellipsoid even though we may not know specifically the parameters (or at least the equatorial radius) of the ellipsoid.

Thus in developing our error model we wish to consider three error sources: altimeter bias, radial orbit error and equatorial radius error.

In order to adjust our data, we decided to fit (through an approximate error model) the sea surface heights defined along an arc segment to the geoid heights defined by a set of potential coefficients. We would then find the parameters of the error model that would yield the best agreement between the potential coefficient model and the adjusted sea surface heights (which had been corrected for tidal effects).

For simplicity, consider this adjustment for a single arc. We write for a single point on the arc:

$$(2) \quad N_b + B\Delta = N_R + v$$

where

N_b is the sea surface height based on the Geos-3 data from the Wallops Flight Center;

N_R is the geoid undulation implied by a set of potential coefficients;

Δ represents parameters of the error model;

- B is the design matrix or coefficients of the error model parameters;
v is the residual after the adjustment

The adjusted (bias removed) sea surface height would be:

$$(3) \quad N_{ADJ} = N_b + B \Delta$$

For our work the geoid undulations were computed from the following (Rapp, 1971):

$$(4) \quad N_R = \frac{GM}{\gamma r} \sum_{\ell=2}^{\ell_{MAX}} \left(\frac{a}{r} \right)^{\ell} \sum_{m=0}^{\ell} (\bar{C}_{\ell m} \cos m \lambda + \bar{S}_{\ell m} \sin m \lambda) \bar{P}_{\ell m}(\sin \bar{\varphi})$$

where:

- GM is the geocentric gravitational constant;
r is the geocentric distance to the point at which N_R is being computed;
a is an equatorial radius;
 $\bar{C}_{\ell m}, \bar{S}_{\ell m}$ are fully normalized potential coefficients with $\bar{C}_{2,0}$ and $\bar{C}_{4,0}$ referred to an ellipsoid of a specified flattening;
 $\bar{P}_{\ell m}$ are the fully normalized Legendre functions;
 $\bar{\varphi}, \lambda$ are the geocentric latitude and longitude;
 γ is the normal gravity at $\bar{\varphi}$

A number of different error models and ℓ_{MAX} values were used to determine their effect on the adjusted undulations as given by equation (3), and on the fit itself as represented by the root mean square residual. The error models tested are shown in Table 3.

Table 3

Form of Error Model Tested

Model	Form
1	$X_1 + X_2 \cos \psi + X_3 \sin \psi$
2	X_1
3	$X_1 + X_2 (t - t_0)$
4	$X_1 + X_2 (t - t_0) + X_3 (t - t_0)^3$

Model 1 was suggested by Rummel (1976) for use with arcs of length greater than $22^{\circ}5$. In this model ψ is the spherical distance from the equator crossing. In models 3 and 4 t is the time of observation and t_0 is a reference time.

Six arcs of various lengths were selected for testing. The arcs described in Table 4.

Table 4

Arc Information for Model Tests

Number	No. of obs.	Length (km)
1	533	7570
2	67	970
3	262	3600
4	106	1700
5	603	14100
6	355	5230

The first test was to see the effect of l_{MAX} on the adjusted undulations or sea surface height. To find this, the first three arcs in Table 4 were separately fitted to the GEM 7 coefficients to degree 16 using error model 1 for arcs 1 and 3 and model 2 for arc 2. The fit was repeated with $l_{MAX} = 4, 8$, and 12 with the adjusted undulations being compared to those found from the degree 16 solution. The root mean square differences are given in Table 5.

Table 5

Root Mean Square Adjusted Sea Surface
Height Differences vs l_{MAX} with GEM 7

Arc	Degree 16 Adjustment Minus Adj. to Specified l_{MAX}		
	$l_{MAX} = 12$	$l_{MAX} = 8$	$l_{MAX} = 4$
1	± 0.6 m	± 3.3 m	± 3.5 m
2	± 1.6 m	± 1.5 m	± 7.7 m
3	± 1.2 m	± 3.9 m	± 7.9 m

We conclude that at the ± 1 meter level the adjusted undulations are sensitive to the chosen l_{MAX} .

A second test was run to determine the effect of errors in the GEM 7 potential coefficients on the adjusted sea surface heights. To do this a modified GEM 7 coefficient set was generated by adding to each of the coefficients a number dependent on the standard deviation of that coefficient as given by Wagner (1976). The previous adjustments were repeated and the adjusted undulations compared. These results are shown in Table 6.

Table 6

Root Mean Square Adj. Sea Surface Height Differences Between
Original GEM 7 and Modified GEM 7 Potential Coefficients

Arc	ℓ_{MAX}			
	16	12	8	4
1	± 1.4 m	± 1.1 m	± 0.3 m	± 0.2 m
2	± 2.3 m	± 1.3 m	± 1.1 m	± 0.1 m
3	± 2.0 m	± 1.1 m	± 1.1 m	± 0.2 m

We conclude that at the ± 1 m level the errors in the potential coefficients reflect in the adjusted undulation values when only single arcs are being adjusted.

We next tested the fits obtained by the different error models using the GEM 7 coefficients to degree 16. These results are given in Table 7.

Table 7

RMS Residual After Adjustment of Test Arcs
Using Different Error Models and GEM 7 to Degree 16

Arc	Error Model			
	1	2	3	4
1	± 2.73 m	± 3.67 m	± 3.66 m	± 2.74 m
2	0.75	2.60	1.32	0.75
3	1.45	2.75	2.20	1.45
4	6.97	8.12	8.11	6.97
5	3.40	4.13	3.38	3.36
6	2.81	3.27	3.05	2.81

We see that assuming a constant bias (model 2) gives the poorest fit to the data. Models 1 and 4 give essentially identical results while model 3 gives somewhat poorer results than either 1 or 4. One would prefer to choose, from these tests, either error model 1 or 4. However, later tests conducted using global data sets showed that it was difficult to separate in the adjustment the X_2 and X_3 unknown model parameters. We consequently decided to adopt model 3 for our error model when the arc length was greater than 22°. Arguments by Rummel (1977) suggest that for arc lengths below this, with the use of the GEM 7 reference field, only a single bias term should be solved for (i.e. error model 2). Such a procedure was followed in the actual computations to be described in a subsequent section.

Sea Surface Topography Modeling

The tests conducted so far assume that the sea surface heights correspond to the geoid. In fact, they do not because of the existence of sea surface topography caused by prevailing winds, currents, etc. in the oceans. We consequently felt that we should try to see if correcting our sea surface heights for sea surface topography using available information would be of help.

To do this, the sea surface topography map given by Lisitzin (1974, p. 149) was digitized in such a way (Katsambalos, 1977) that an interpolated value could be obtained at a specified point. A mean value of 280 dyn. centimeters was subtracted to give the actual sea surface topography with respect to the geoid.

With this data, error model 1 was used to fit the corrected (for sea surface topography) altimeter derived undulations. The results of these fits are given in Table 8.

Table 8

RMS Residuals After Adjustment With Error Model 3,
With and Without Sea Surface Topography

Arc	With Sea Surface Topography	Without Sea Surface Topography
1	±2.75 m	±2.73 m
2	0.75	0.97
3	1.45	1.52
4	6.97	6.99
5	3.40	3.43
6	2.81	2.84

We can see that no significant improvement in fit is obtained by incorporating sea surface topography estimates in our data. However, slight improvements are noted and further tests should be made. For this report we will not consider any corrections for sea surface topography.

The Adjustment Model

We have discussed a technique for removing bias from the sea surface heights using a simple model such as equation (2) with a specific error model being chosen from Table 3. In addition, we can incorporate into our adjustment an equation to represent the fact that when two arcs cross, the resultant sea surface height should be approximately the same. The two heights will not be identical because of sea state and observational noise. We now develop the mathematical model considering these ideas using a somewhat different notation than Rummel (1976, 1977).

We start by writing a matrix form of equation (2), considering an unspecified number of arcs. Then (2) becomes:

$$(5) \quad \underline{N}_b + \underline{B} \underline{\Delta} = \underline{N}_R + \underline{v}$$

where

$\underline{N}_b$, $\underline{N}_R$, $\underline{v}$ and $\underline{\Delta}$ are column vectors, and
 $\underline{B}$ is the observation coefficient matrix.

Equation (5) is of the following form (Mikhail, 1976, p. 111):

$$(6) \quad \underline{A} \underline{v} + \underline{B} \underline{\Delta} = \underline{f}$$

where, by analogy with (2), we have:

$$(7) \quad \begin{aligned} \underline{A} &= -\underline{I} \\ \underline{f} &= \underline{N}_R - \underline{N}_b \end{aligned}$$

The cross-over model for the i and j th arcs can be written as:

$$(8) \quad N_{\text{ADJ}(i)} - N_{\text{ADJ}(j)} = C_{ij}$$

where N_{ADJ} is the adjusted undulation (or sea surface height) and C_{ij} is the cross-over discrepancy after the adjustment. Using equation (3), (8) can be written as:

$$(9) \quad N_b(i) + B_i \Delta_i - N_b(j) - B_j \Delta_j = C_{ij}$$

Equation (9) can be written as:

$$(10) \quad -C_{ij} + B_i \Delta_i - B_j \Delta_j = N_b(j) - N_b(i)$$

which is of the general form of (6) with:

$$(11) \quad \begin{aligned} C_{ij} &= v \\ A &= -I \\ f &= N_b(j) - N_b(i) \end{aligned}$$

Considering all cross-overs between all arcs considered in the adjustment, we can write a general cross-over observation equation as:

$$(12) \quad -\underline{v}_c + \underline{B}_c \underline{\Delta} = \underline{f}_c$$

where

$$\underline{B}_c = [B_{i,j} - B_j]$$

Equation (5) can also be written in the following form:

$$(13) \quad -\underline{v}_A + \underline{B}_A \underline{\Delta} = \underline{f}_A$$

where

$$f_A = N_R - N_b$$

We can combine (12) and (13) into a single matrix equation:

$$(14) \quad - \begin{bmatrix} v_A \\ v_c \end{bmatrix} + \begin{bmatrix} B_A \\ B_c \end{bmatrix} \Delta = \begin{bmatrix} f_A \\ f_c \end{bmatrix}$$

We let W_A be the weight matrix of the altimeter derived undulations, and W_c the weight matrix of the cross-over observation equations. Then a solution for Δ of (14) is sought such that:

$$(15) \quad v_A^t W_A v_A + v_c^t W_c v_c = \text{a minimum}$$

Under this specification the general solution of:

$$(16) \quad Av + B \Delta = f$$

is

$$(17) \quad \Delta = N^{-1} f$$

where

$$(18) \quad N = B^t (A W^{-1} A^t)^{-1} B$$

$$(19) \quad t = B^t (A W^{-1} A^t)^{-1} f$$

In our case $A = -I$ so that (18) and (19) become:

$$(20) \quad N = B^t W B$$

$$(21) \quad t = B^t W f$$

Considering (14) and (16) we also have:

$$B = \begin{bmatrix} B_A \\ B_c \end{bmatrix} ; \quad f = \begin{bmatrix} f_A \\ f_c \end{bmatrix} ; \quad W = \begin{bmatrix} W_A & 0 \\ 0 & W_c \end{bmatrix}$$

so that equation (17) becomes:

$$(22) \quad \Delta = [B_A^t W_A B_A + B_c^t W_c B_c]^{-1} [B_A^t W_A f_A + B_c^t W_c f_c]$$

Knowing the error model parameters from (22) we can determine the adjusted undulations from:

$$(23) \quad N_{ADJ} = N_b + B \Delta$$

while the undulation residuals would be:

$$(24) \quad v = N_{ADJ} - N_R$$

The cross-over discrepancy, after the adjustment, would be given by equation (8).

If there were no cross-over observations, the normal equations in (22) would be block diagonal where the size of the block would correspond to the number of unknowns for the error model for the specified arc. The block diagonal nature of the normal equations reflects the fact that without the cross-over observations, each arc can be adjusted separately.

The cross-over observation equations destroy the block diagonal nature of the normal equations. The resulting normal equations in (22) will have the block diagonal terms, and also the off diagonal terms reflecting the cross-over information between the different arcs. Since, a priori, there will be no particular pattern to the normal equations, the solution of them may be time consuming as the number of unknowns to be solved for may vary from 1500 to 4000 or more.

Although the number of unknowns in the normal equations may be large, we also expect many zero elements to appear. This suggests that the order of the unknowns in the normal equations be arranged in such a way that the column profile (for example) of a set of normal equations be minimized so that most zero elements are not stored. Then very efficient computations for the unknowns can be made. A procedure for minimizing the column profile in normal equations has been described by Snay (1976a, b) for possible use in the solution of normal equations arising in the adjustment of triangulation networks. The algorithm and Fortran program developed by Snay was used in our altimeter adjustment, enabling a large number of arcs and cross-overs to be handled in relatively small amounts of computer time on our IBM 370/168 operating under MVS.

Adopted Geodetic Constants

For a number of computations to be performed it will be necessary to adopt the best available set of geodetic parameters. For these purposes, we use the values given in Moritz (1975):

$$\begin{aligned}a &= 6378140 \text{ m} \\GM &= 3.986005 \times 10^{-14} \text{ m}^3 \text{ s}^{-2} \\J_2 &= 1082.63 \times 10^{-6} \\\omega &= 7.292115 \times 10^{-5} \text{ rad s}^{-1}\end{aligned}$$

The implied flattening is 1/298.257 and the equatorial gravity is 978031.8 mgals. At the 0.1 mgal level there is no difference between the gravity formula of these constants and that of the Geodetic Reference System 1967.

The Actual Altimeter Adjustments

In order to adjust the altimeter arcs shown in Figure 1, we first decided to use the GEM 9 potential coefficients (Lerch et al., 1977) to degree 20. This coefficient set is based only on satellite data with no terrestrial gravity data in the solution. In addition, it is given to a higher degree than GEM 7, and tests reported by Lerch indicate the GEM 9 is an improved solution with respect to GEM 7.

We developed a procedure to develop the cross-over observation equations and discrepancies starting from information given in Brown and Schroeder (1977) and kindly provided to us on tape by Brown. With information in Brown and Schroeder, a procedure was developed to pass through the edited tapes to find all cross-overs in a specified geographic region (which could be world wide). This program would then interpolate to the exact cross-over point the sea surface height and develop the observation equation coefficients. A more detailed explanation of the crossover determination may be found in Herbrechtsmeier (1977).

To implement the discussion in the previous paragraphs, we decided to first perform a primary adjustment using a select set of long arcs that had a good geographic distribution. The number of such arcs were chosen to be sufficiently large such that good coverage with available data would be obtained, and the computer time and storage requirements be within our available means. The location of the 854 primary arcs are shown in Figure 2.

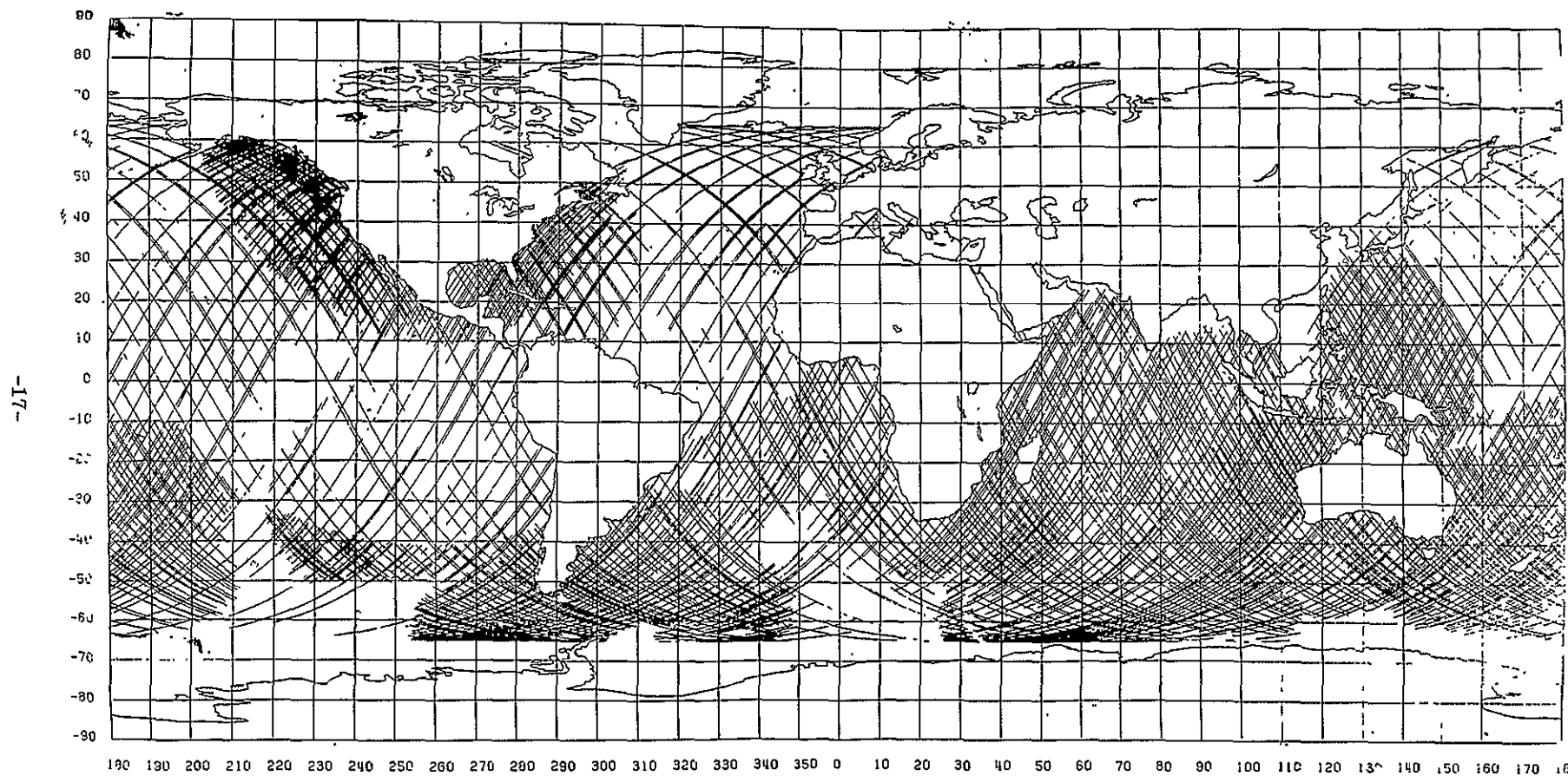


Figure 2. Location of Arcs Used in the Primary Adjustment

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After adjusting the primary arcs, adjustments were planned for regional areas in which sufficient altimeter data was available. In these regional adjustments, the primary arcs were held fixed while the non-primary arcs in the region received adjustment using the standard procedure using arc and cross-over observation equations. The location of the six regional adjustment areas is shown in Figure 3. The designations and locations are given in Table 9.

Table 9

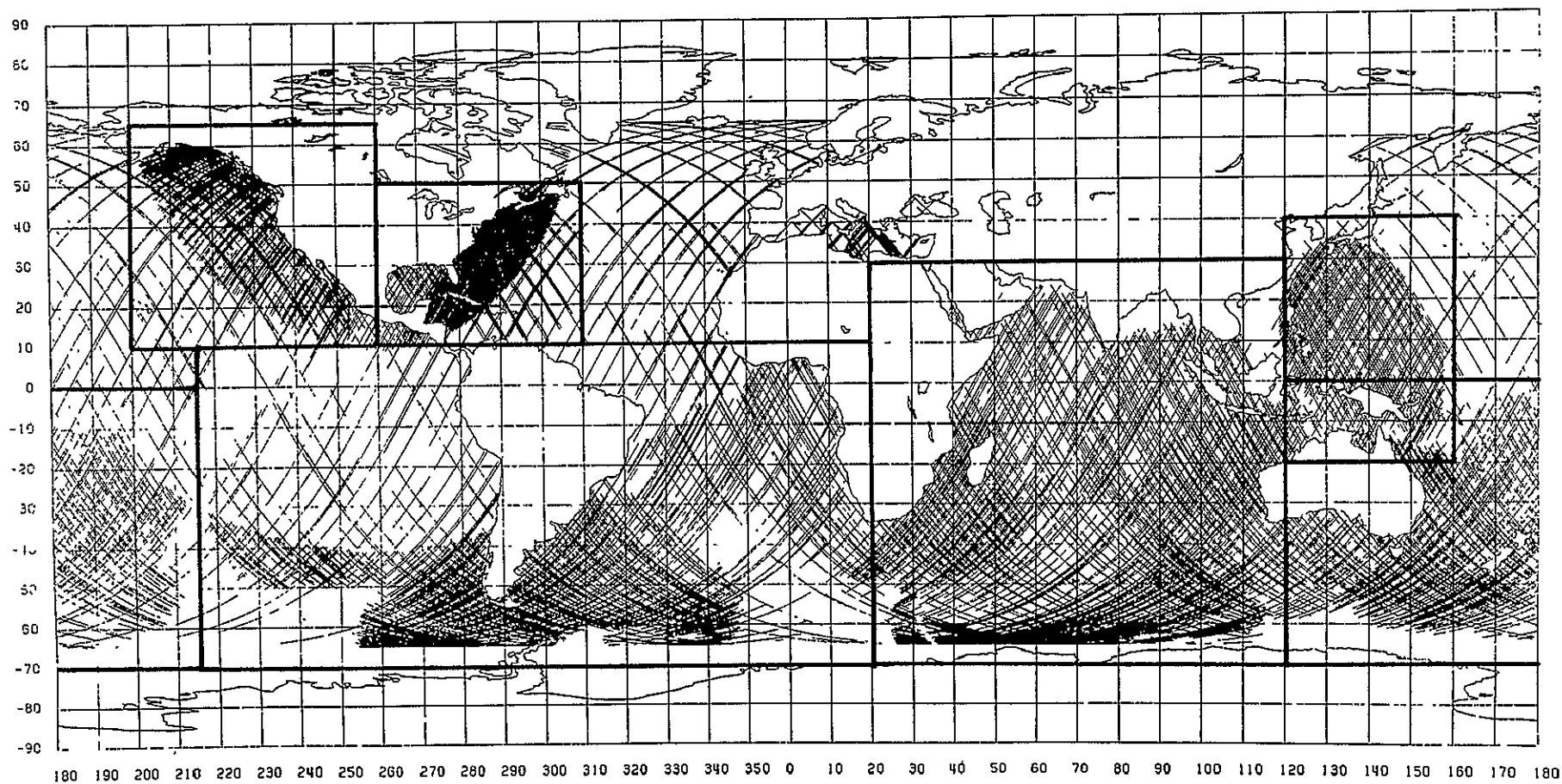
Regional Adjustment Locations

Name	Location	
Alaska	$\phi: 10^{\circ}$ to 66°	$\lambda: 200^{\circ}$ to 260°
Calibration	$\phi: 10^{\circ}$ to 50°	$\lambda: 260^{\circ}$ to 310°
Indian Ocean	$\phi: -70^{\circ}$ to 30°	$\lambda: 20^{\circ}$ to 120°
Philippines	$\phi: -20^{\circ}$ to 40°	$\lambda: 120^{\circ}$ to 150°
New Zealand	$\phi: -70^{\circ}$ to 0°	$\lambda: 120^{\circ}$ to 214°
South America	$\phi: -70^{\circ}$ to 10°	$\lambda: 214^{\circ}$ to 20°

In carrying out the adjustments the standard deviations given for the altimeter measured height were used in computing the W_A matrix. These standard deviations ranged from 0.25 to 8.0 meters with an average value being on the order of 0.7 meters. To enforce the crossover constraints (or observation equation) the standard deviation of this observation equation was chosen as ± 0.05 m giving a weight of $1/400$. In the regional adjustments, a weight of $1/800$ was given to those cross-overs involving a primary arc and a secondary arc. All observation equations were regarded as independent.

In carrying out the global and regional adjustments it was first necessary, in some cases, to carry out an initial adjustment. We then examined the cross-over discrepancies after the adjustment. In some cases certain arcs gave excessively large (greater than 3.5 meters) cross-over discrepancies. Such arcs were rejected from the data set and the adjustment repeated. Some statistical information concerning the global adjustment and each of the regional adjustments is given in Table 10.

From Table 10 it is readily apparent that the adjustment process has been successful in the reduction of the a priori cross-over discrepancies. The discrepancies after the adjustment are of the expected accuracy of the instrument.



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Figure 3
Location of the Six Regional Adjustment Areas

Table 10

Information Related to Primary and Regional Adjustments

Region	Arcs	Number of;			Crossover Discrepancies	
		Unknowns	Obs.	Cross-overs	a priori	a posteriori
Global	854	1568	260789	11406	± 8.27 m	± 0.56 m
Alaska	75	93	12739	1575	9.63	0.60
Calibration	345	478	46617	28920	7.77	0.65
Indian Ocean	143	251	35587	4912	8.77	0.50
Philippines	42	72	9634	662	13.59	0.69
New Zealand	104	173	25486	3193	8.27	0.60
South America	185	281	34892	4981	9.81	0.57

We show in Figure 4 a histogram plot of the cross-over discrepancies for the global adjustment. Although tests show these discrepancies are not normally distributed, the cross-over discrepancy distribution appears reasonable.

At this point we have a set of sea surface heights (or geoid heights), referred to the general terrestrial ellipsoid, and for which we have removed the effects of altimeter bias, orbit error, etc. These adjusted values can now be used for making geoid maps, the determination of gravity anomalies, or other such dependent quantities.

The Dependence of the Adjusted Sea Surface Heights on the GEM 9 Potential Coefficients

Since we have fitted, by a first degree polynomial, the altimeter derived data, there is some concern about the dependence on GEM 9 in the final result. From the results previously reported in Tables 5 and 6, we have seen the dependence of the adjusted undulations along single arcs on potential coefficient variations. However, what may hold along a single track may not hold when the cross-over observation equations are introduced.

To see the effect of potential coefficient changes on the adjusted values of the sea surface heights, we repeated the primary adjustment using a modified set of GEM 9 potential coefficients to degree 20. This modified set was determined using the following equations:

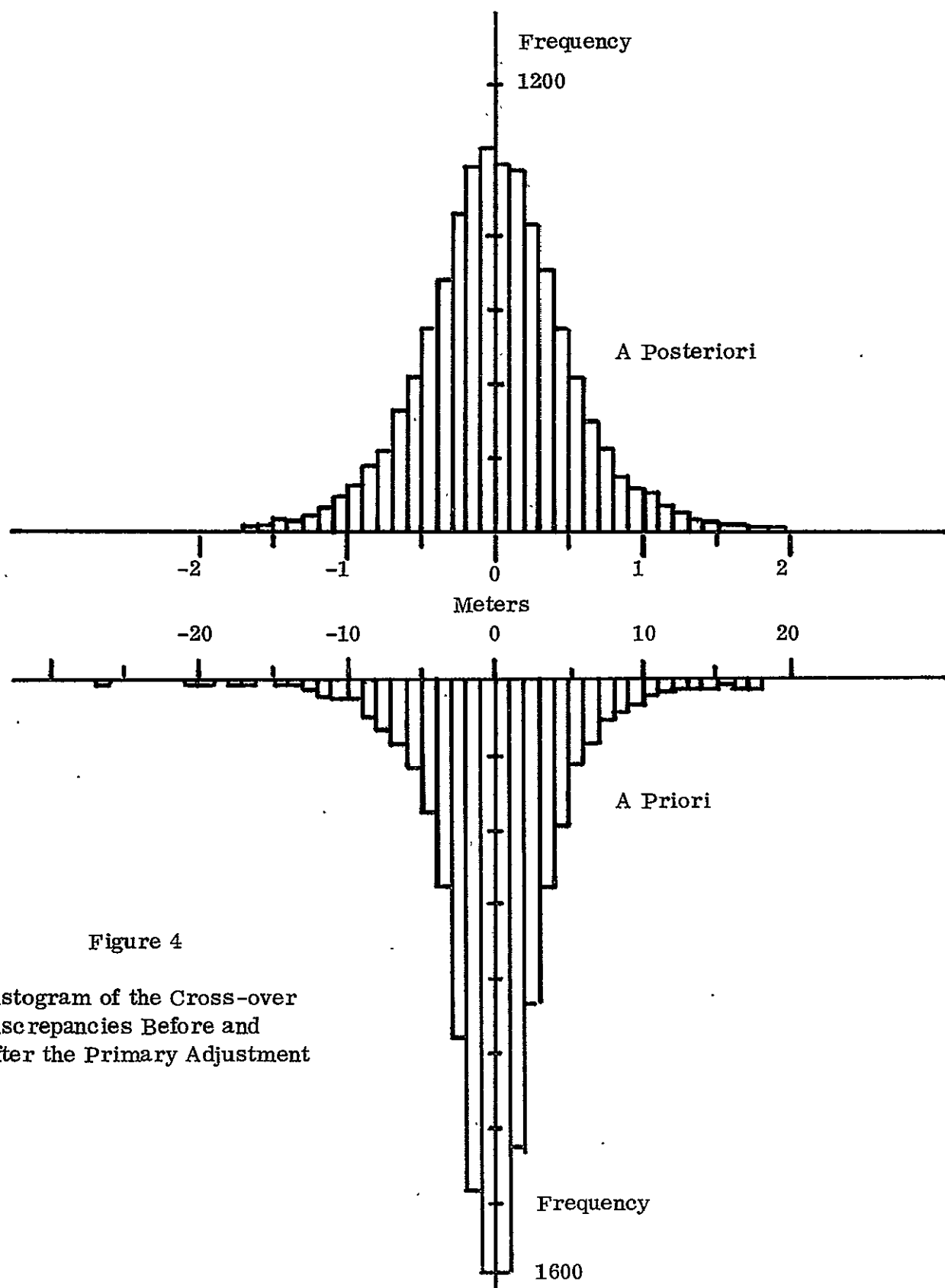


Figure 4

Histogram of the Cross-over
Discrepancies Before and
After the Primary Adjustment

$$(25) \quad \left\{ \begin{array}{c} \bar{C}_{\ell_m} \\ \bar{S}_{\ell_m} \end{array} \right\}_{\text{GEM 9 M}} = \left\{ \begin{array}{c} \bar{C}_{\ell_m} \\ \bar{S}_{\ell_m} \end{array} \right\}_{\text{GEM 9}} + 2 \left\{ \begin{array}{c} d \\ e \end{array} \right\} \left\{ \begin{array}{c} m(\bar{C}_{\ell_m}) \\ m(\bar{S}_{\ell_m}) \end{array} \right\}$$

where m represents the standard deviation for the GEM 9 coefficient as given by Lerch et al. (1977) and d and e are normal deviates drawn from a normal distribution with zero mean and a variance of 1. The factor 2 was used simply to provide a pessimistic error statement.

The modified potential coefficients were then compared to the original coefficient set. The global undulation difference was ± 3.5 meters with the largest difference being 11 meters.

The complete primary adjustment was redone with this modified GEM 9 potential coefficient set. The adjusted sea surface heights were then compared to the corresponding values found from the original solution. The mean difference between the two sets of sea surface heights was 0.07 m while the root mean square difference was ± 0.85 m.

We thus see that a global difference of ± 3.5 meters in the potential coefficient sets has been reduced by a factor of about four in the adjusted sea surface heights. If we accept the original Lerch et al. accuracy estimates as given, the root mean square undulation difference would be about ± 1.7 m and we would expect this error would propagate into about ± 0.4 m in the adjusted sea surface heights. This error is slightly below the average noise level of our observations.

We thus conclude that errors in the GEM 9 coefficients will effect our final adjusted values, but that any error is reduced by a factor of about 4 and in our case, this error will be on the order of ± 0.4 m.

Sea Surface Heights or Geoid Undulations as Derived from the Adjusted Data

The usual geoid maps can be produced from the adjusted data if we assume the geoid and sea surface heights coincide. If we do not make such an assumption, sea surface height maps can be constructed that should be associated with a certain time period. In our case, we choose to produce such maps noting that they refer to a time period from April 1975 through approximately November 1976.

A procedure for constructing these contour maps is described by Kearsley (1977). He has used the regional adjustments to construct 2 m contour maps in the areas shown in Figure 5 which has been taken from his report. Basically, Kearsley has used a least squares prediction procedure, including data noise, to predict a geoid undulation and its accuracy on a uniform grid.

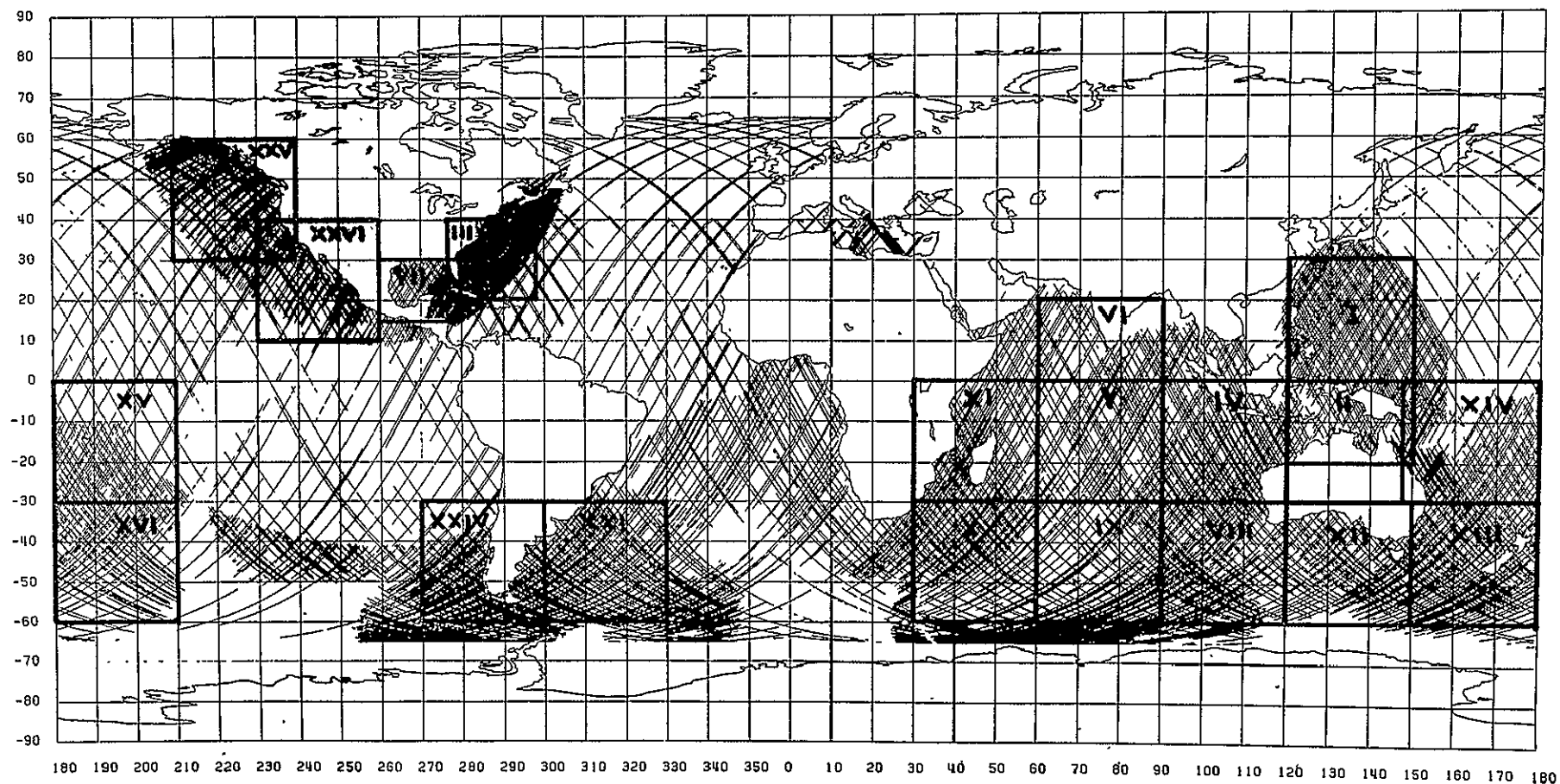


Figure 5
Index of Geoid Maps from Geos-3 Altimetry
(from Kearsley, 1977)

These values were then contoured using a standard contouring algorithm. The data noise was taken as the altimeter measurement standard deviation. No error component due to the errors in the GEM 9 coefficients nor errors in the adjustment process were incorporated. Consequently, the undulation accuracies may be somewhat optimistic.

For purposes of this report, I give two geoid maps taken from the Kearsley report. The first is map III which is off the east coast of the United States. This geoid map and its corresponding accuracy map are given in Figures 6 and 7. No altimeter tracks are plotted on these maps because of the great density of the available data. This geoid (or sea surface height) was compared by Kearsley to a geoid ($N_{R,R}$) derived from the GEM 6 potential coefficients and $1^\circ \times 1^\circ$ terrestrial gravity data by Rapp and Rummel (1975, Table 5), and to the geoid ($N_{M,C}$) by Marsh and Chang (1976) who used the GEM 8 potential coefficients and $1^\circ \times 1^\circ$, $15' \times 15'$ and $5' \times 5'$ mean gravity anomalies. The results of these comparisons are shown in Table 11.

Table 11

Comparisons of the Altimeter Derived Geoid with Ground Truth
Determined from Potential Coefficients and Terrestrial Gravity Data

	$N_{ALT} - N_{R,R}$	$N_{ALT} - N_{M,C}$
Mean Difference	- 0.3 m	- 1.0 m
RMS Difference	± 1.2	± 1.5
[Variance] $^{\frac{1}{2}}$	± 1.2	± 1.1
Number of Comparisons	337	335
Maximum Difference	5.0	9.2
Minimum Difference	- 3.5	- 4.6

From this table we can see that there is a greater systematic difference with the Marsh, Chang geoid than with the Rapp, Rummel geoid. The RMS differences and square root of the variance is consistent with the accuracy of the ground truth geoid, being on the order of ± 1.6 m (Rapp and Rummel, 1975, Table 6). A map of the undulation differences (both $N_{R,R}$ and $N_{M,C}$) with the altimeter geoid reveals slopes that could be indicative of small errors in the potential coefficient sets used in this analysis (Marsh, 1977, private communication).

The second area in which we give the geoid map (and its accuracy) from Kearsley is in the Philippines area (Area I in Figure 5). This information is shown in Figures 8 and 9 where the altimeter tracks are represented by the dashed lines. From Figure 8 we can see the rapid undulation variation across the Philippine Trench, the Mariana Trench and the Izu Trench. The undulation variation between the Philippine Trench and the Mariana and Izu Trench is smooth.

Gravity Anomaly Recovery - Theory

The main proposed goal of our investigation was the determination of mean gravity anomalies from the Geos-3 altimetry data. A number of investigations were carried out under this contract to determine possible techniques for the anomaly recovery. Three such methods are described in a report for this contract by Rummel, Sjöberg and Rapp (1977). These methods involved 1) the use (by Rummel) of the inverse Stokes equation or the Molodensky equation to compute anomalies from geoid undulations; 2) the application of a spectral analysis approach (by Sjöberg) to the anomaly recovery and (3) the use of least squares collocation (by Rapp). These methods are detailed in the Rummel, Sjöberg and Rapp report with each method being tested with altimeter derived undulations that had been determined through the adjustment procedure described in the previous sections of this report.

For the purposes of prediction anomaly recovery, we have chosen the method of least squares collocation (Moritz, 1975). For the specific equations for the anomaly recovery, we have:

$$(26) \quad \Delta g = \underline{C}_{gh} (\underline{C}_{hh} + \underline{D})^{-1} \underline{h}$$

$$(27) \quad m_g^2 = C_{gg} - \underline{C}_{gh} (\underline{C}_{hh} + \underline{D})^{-1} \underline{C}_{hg}$$

where

- Δg : the predicted gravity anomaly (either a point or mean anomaly depending on the interpretation of the covariances);
- $\underline{h}$: a column vector of the given geoid undulations (or sea surface heights);
- $\underline{C}_{gh}$: the row vector containing the covariance between the anomaly being predicted and the given geoid undulation;
- $\underline{C}_{hh}$: the square, symmetric matrix containing the covariances between the given geoid undulations;
- $\underline{D}$: the error-covariance matrix of the given geoid undulations which was taken, in our computations, as a diagonal matrix whose elements corresponded to the square of the standard deviation of the altimeter measurement;

Figure 6

Geoid Undulations in Geos-3 Calibration Area
From Adjusted Altimeter Data
Contour Interval: 2 meters

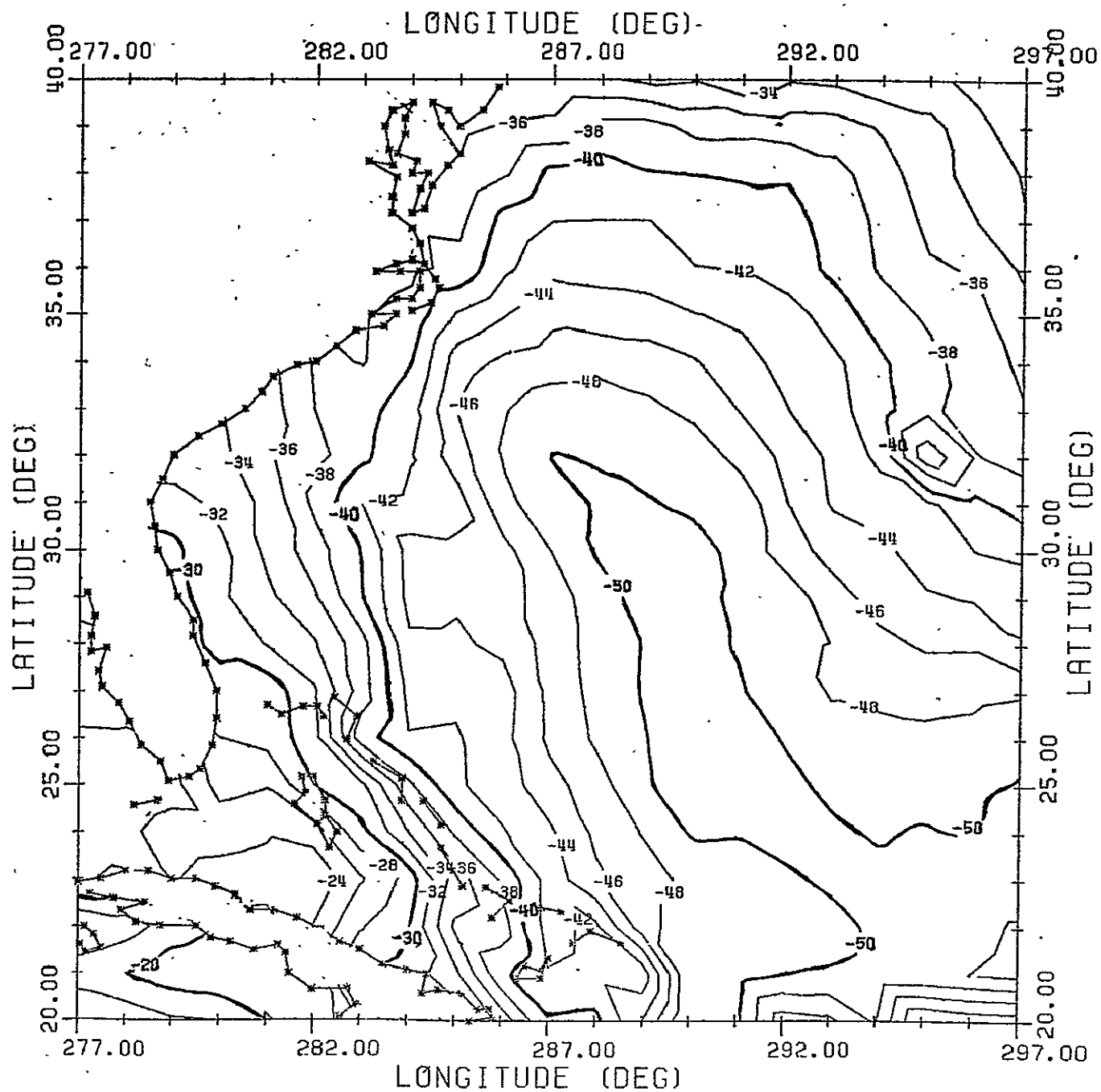


Figure 7

Geoid Undulation Accuracy in Geos-3 Calibration Area
From Adjusted Altimeter Data
Contour Interval: 0.5 meters

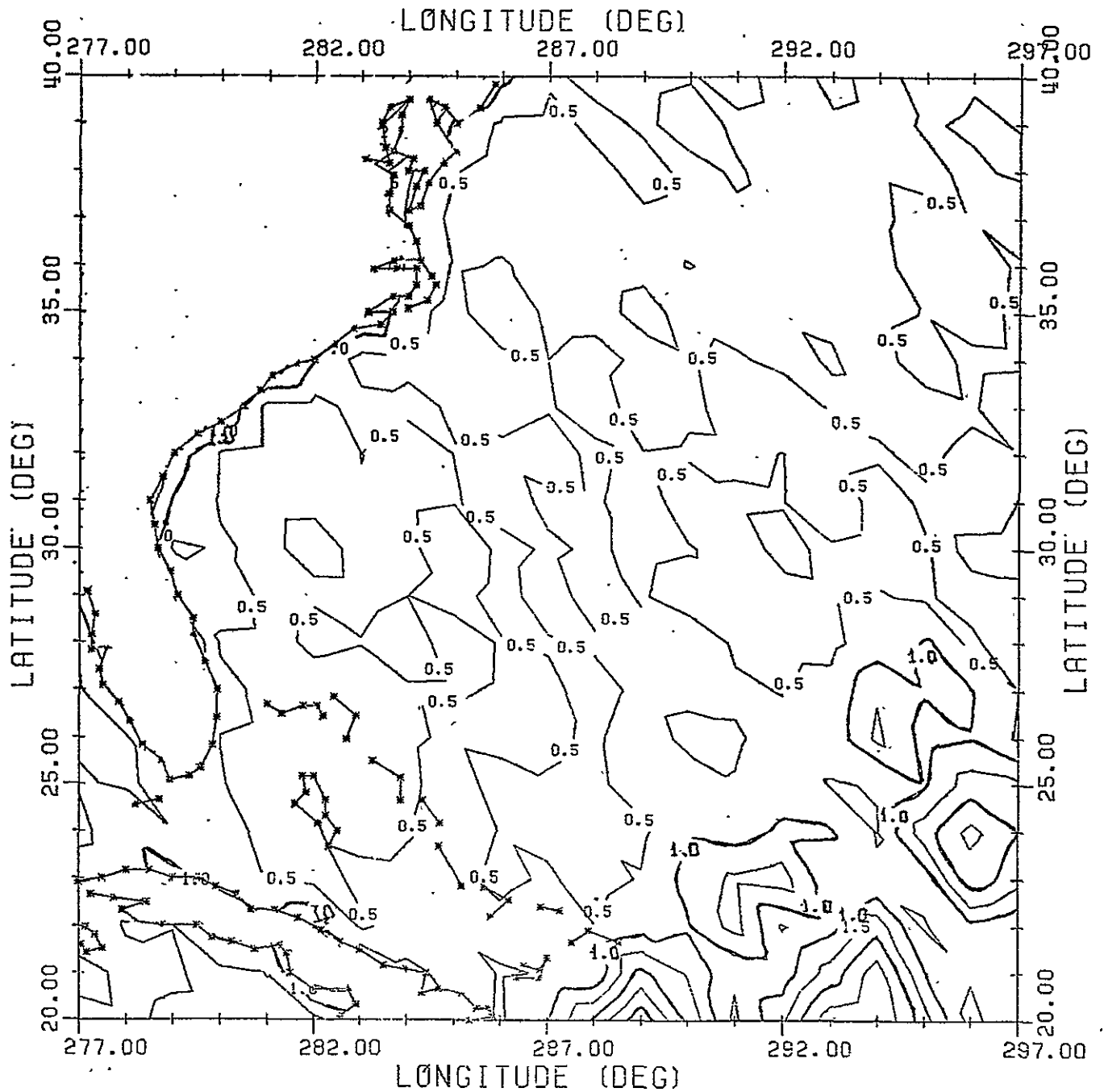
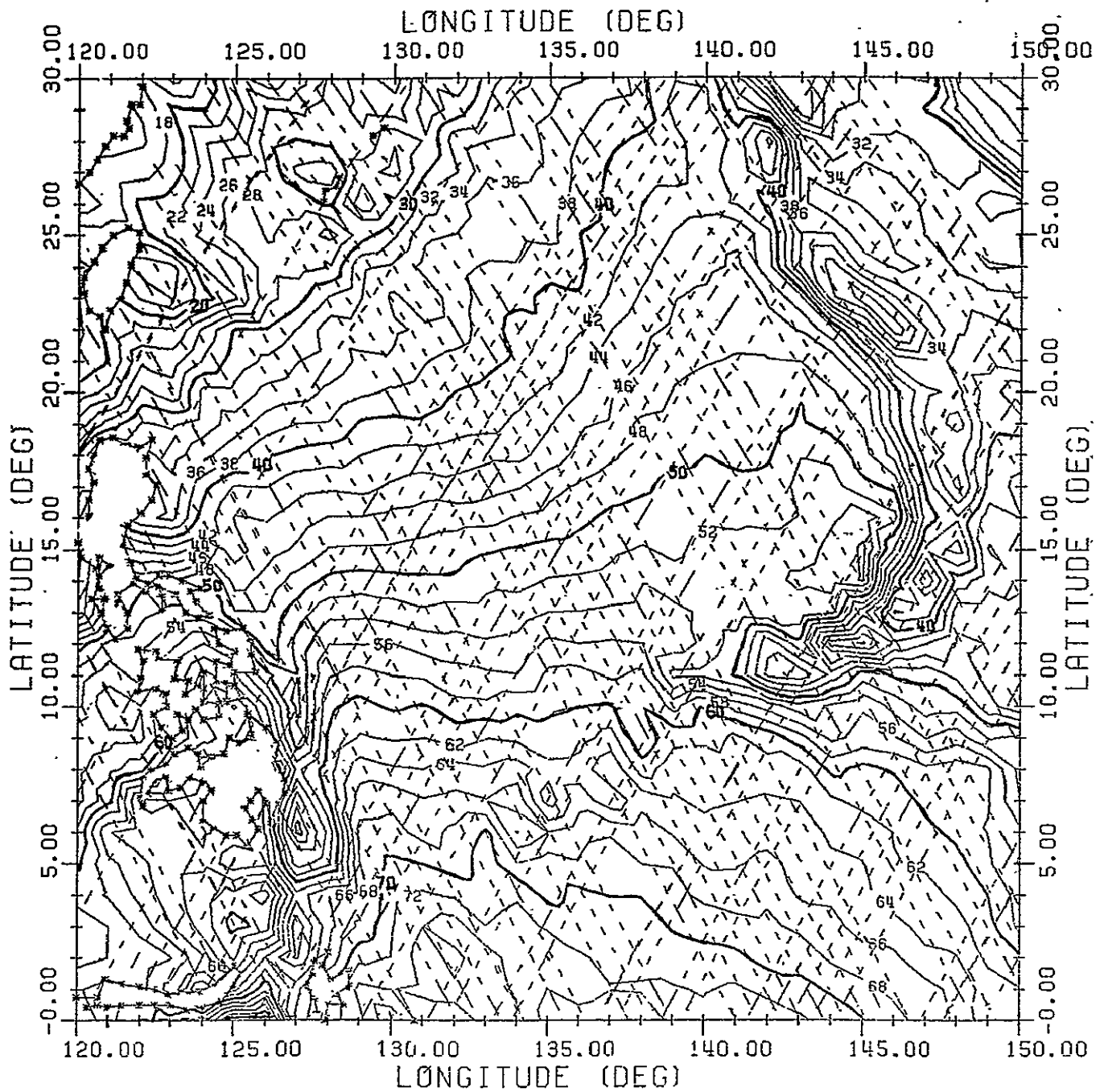


Figure 8

Geoid Undulations in the Philippines
From Adjusted Altimeter Data
Contour Interval : 2 meters



- C_{gg} : the expected mean square value (variance) in a global sample, of the anomaly being predicted;
 m_g : the predicted standard deviation of the predicted anomaly

We not only intend to predict the mean anomalies in a block, but the mean geoid undulations. To do this we write a similar set of equations to (26) and (27):

$$(28) \quad N = \underline{C}_{Nh} (\underline{C}_{hh} + D)^{-1} \underline{h}$$

$$(29) \quad m_N^2 = \underline{C}_{NN} - \underline{C}_{Nh} (\underline{C}_{hh} + D)^{-1} \underline{C}_{hN}$$

In this case:

- N : the predicted geoid undulation;
 $\underline{C}_{Nh}$: the row vector containing the covariance between the undulation being predicted and the given geoid undulation;
 $\underline{C}_{NN}$: the expected mean square value (variance), in a global sample, of the undulation being predicted;
 m_N : the predicted standard deviation of the predicted anomaly

We note that the matrix to be inverted in (26) and (27) is identical to the one to be inverted in (28) and (29).

The interpretation of the predicted quantity as a point or mean value depends on the interpretation of or determination of the covariances that are used in equations (26) through (28). In our computations we intend to use the point covariance function developed in Tscherning and Rapp (1974) on the basis of a hypothetical anomaly degree variance model. If we are predicting point undulations and point anomalies, the covariances from subroutine COVA (in Tscherning and Rapp) can be used directly. If we are determining mean anomalies or mean undulations, the appropriate mean covariance functions must be derived. There are a number of ways to do this with the technique chosen here to be one of numerical integration. Consider two blocks A_1 and A_2 whose dimensions are $a \times b$ (for A_1) and $a' \times b'$ for A_2 . These blocks are, for now, considered to be located on a plane in non-identical positions. Now let $C(P, Q)$ be a point covariance function between points P (in A_1) and Q (in A_2). Then we can write (following from equation (7-82) in Heiskanen and Moritz, 1967):

$$(30) \quad C_{A_1 A_2} = \frac{1}{(ab)(a'b')} \int_{x=0}^a \int_{y=0}^b \int_{x'=0}^{a'} \int_{y'=0}^{b'} C(x, y, x', y') dx dy dx' dy'$$

If we now let:

$$a = ndy; \quad b = ndx; \quad a' = ndy'; \quad b' = ndx'$$

we can express (30) in the following numerical integration form:

$$(31) \quad C_{A_1 A_2} = \frac{1}{n^4} \sum_{i=1}^n \sum_{j=1}^n \sum_{i'=1}^n \sum_{j'=1}^n C(x_i, y_i, x_{i'}, y_{j'})$$

The accuracy of this computation will improve as n increases, but so will the computation time. One wishes to choose n to be as small as possible being consistent with the accuracy objectives of the computations. In the computations to be described in this report, we choose $n = 10$ when dealing with 5° anomalies and $n = 5$ when dealing with $1^\circ \times 1^\circ$ anomalies. In addition, we interpreted the altimeter measurement to be a point value, although the measurement has a finite (but small) footprint.

Gravity Anomaly Recovery - Test Results

The implementation of the preceding theory required a number of decisions on data selection, reference fields, computational efficiencies, etc. that had to be made before production computations could be started. We describe in this section some of these computations.

Grid Interval:

A number of prediction tests were made to select the optimum value of n appearing in equation (31). For 5° anomaly predictions, n was chosen as 10 and for 1° predictions, n was chosen as 5. Improvement, caused by increasing n , in the anomaly predictions (and accuracy) could be on the order of 0.3 mgals, while for undulation estimation, it would be on the order of 0.1 meters.

Covariance Tabulation:

The computation of the needed covariances from COVA (Tscherning and Rapp, 1974) can be expensive when many computer subroutine calls are made, such as is done in the numerical integration. To get around this, tables were constructed of the needed covariances as a function of the spherical distance at 0.05 interval. These tables were stored in the program with linear interpolation being used to determine the needed covariance. Such a procedure considerably reduced the computer time and caused no errors in the final results at the 0.1 mgal and 0.1 meter levels.

Plane Coordinates:

The covariance functions are usually given as a function of the spherical distance ψ separating the points of interest. This spherical distance is usually computed given the latitude and longitude of the two points involved. This requires the solution of the spherical law of cosines and the use of an arc cosine subroutine. Since we planned on extensive computations with this procedure, we examined the idea of getting away from spherical coordinates and use plane coordinates instead. The use of plane coordinates might be justified due to the fact that we would be working, for each prediction, with data in a limited part of the earth.

The type of plane coordinate system should be simple, should have small length distortion, and should have an x coordinate (positive east) that was independent of latitude changes, and the y coordinate (positive north) independent of longitude, so that the numerical integration technique could simply be applied. Two such sets of mapping equations were tested. They were the "Carte Parallelogrammatique" (Pearson, 1977, p. 250) and a modified Mercator projection where the distance is held true at a specified latitude. Not noting any significant differences between the results of the two projections, we elected to use the following form of the Carte Parallelogrammatique projection:

$$(32) \quad x = R \cos \varphi_0 (\lambda - \lambda_0)$$

$$(33) \quad y = R (\varphi - \varphi_0)$$

where R is a mean earth radius (6371 km), φ_0 , λ_0 are the coordinates of the midpoint of the 5° block being predicted, and φ , λ are the coordinates of the point whose x, y coordinates are being determined. The spherical distances needed for covariance evaluation were found by multiplying the plane coordinate distance by RAD/R where RAD is the radian conversion to degrees factor.

Limited tests with predictions with plane coordinates gave no changes to predicted N values and standard deviation at the 0.02 meter level and at less than the 0.1 mgal level for the anomaly standard deviation. All further computations used plane coordinates except for a subroutine computing the block variances, which was retained in spherical form.

Data Selection:

Previous experience (Rapp, 1974) and Rummel and Rapp (1977) had shown us two facts: 1) only data with about 3° of the edge of a mean anomaly block was needed when a high degree reference field on the order of 12-20 was used; 2) the computational effort in selecting data for a single block and the subsequent matrix inversion required a significant amount (about 2 min. of IBM 370/168 time). Although this time may seem short by itself, when one contemplates over 10,000 separate mean anomaly computations, the actual time and expense is not reasonable.

In order to reduce the required computer time, we decided to select the data with respect to the 5° equal area block whose mean anomaly was being estimated. Specifically, all data within a 3° border surrounding the 5° block was selected for possible use. This data was then selected so that all data outside a spherical radius of ψ° was detected (ψ was usually 4° from the center of the 5° block). We then said that the maximum matrix that we would invert would be about 420×420 . The available data was then selected to be every n th point where n was chosen so that the final data set did not exceed 420 (although some tests were made up to 475). We then used this data set to compute the matrix inverse needed in equations (27), (28), (29) and (30). Then the appropriate mean covariance functions were determined to predict, first the 5° block mean (of Δg and N), and then the prediction of all $1^\circ \times 1^\circ$ mean values that fell within the 5° equal area block. Thus, if there are s $1^\circ \times 1^\circ$ values in the 5° block, we will save s data selections and s inversions of a 420×420 (roughly) matrix. The time saving is obvious. However, we do potentially increase the error in our prediction because the data will not be selected optimally for each block being predicted. This is a compromise that one must accept for production predictions.

A number of tests were made comparing the $1^\circ \times 1^\circ$ anomalies predicted separately, and predicted as part of the $1^\circ \times 1^\circ$ anomalies within the 5° equal area block.

Some tests were run that showed the error in the $1^\circ \times 1^\circ$ anomaly prediction caused by the 5° data selection was on the order of 0.5 mgals reaching 5 mgals in one case (where the 5 mgals was less than the predicted standard deviation of the anomaly). Considering the tests made, the error attributed to the anomaly prediction caused by the prediction of the $1^\circ \times 1^\circ$ anomaly with the 5° anomaly data set is probably on the order of 1 to 2 mgals, considerably below the expected ± 6 mgal accuracy in the anomalies to be predicted.

A number of tests were also made specifying the data interval along a profile such that every n th point would be used. In average coverage areas with respect to the altimeter data, n was 6. In sparse areas n could be 2 or 3 (no n below 2 was allowed for stability reasons in the matrix inverse). In the densest area, n could reach 19. In these latter cases, special

tests were made to see if a significant improvement in accuracy could be made by reducing n (or increasing the data points selected) with the subsequent increase in computer time. Comparing the predicted anomalies with terrestrial anomalies on an area off the east coast of the United States, the improvement in going from an n of 15 to an n of 12 was only 7%, which was considered negligible. These and other tests were used to establish the maximum number of data points to be used as around 420, provided they were chosen in a manner such that all areas had data, if possible.

Influence of the Reference Field on the Anomaly Prediction:

The gravity anomalies and geoid undulations predicted from (26) and (28) refer to the reference gravity field to which the given geoid undulations (h) and the covariances are referred. Usual practice is to give the final values with respect to an equipotential ellipsoid model, but a higher degree model such as GEM 9 could be used as a reference. Then (26) and (28) would become:

$$(32) \quad \Delta g = \underline{C}_{ghR} (\underline{C}_{hhR} + \underline{D})^{-1} (\underline{h} - \underline{h}_R) + \Delta g_R$$

$$(33) \quad N = \underline{C}_{NhR} (\underline{C}_{hhR} + \underline{D})^{-1} (\underline{h} - \underline{h}_R) + N_R$$

where the subscript R indicates a value given with respect to the adopted reference field. The needed covariances can be obtained from subroutine COVA previously discussed. The reference undulation, h_R , can be computed from equation (4). The reference gravity anomaly, Δg_R , can be computed from:

$$(34) \quad \Delta g_R = \frac{GM}{r^2} \sum_{\ell=2}^{\ell_{MAX}} (\ell-1) \left(\frac{a}{r}\right)^{\ell} \sum_{m=0}^{\ell} (\bar{C}_{\ell m} \cos m \lambda + \bar{S}_{\ell m} \sin m \lambda) \bar{P}_{\ell m}(\sin \varphi)$$

For reference fields to degree 20, (34) is sufficiently accurate for $1^\circ \times 1^\circ$ mean values when the coordinates of the center point are taken. For the larger 5° equal area block the following integrated form of (34) should be used:

$$(35) \quad \Delta \bar{g}_R = \frac{GM}{r^2 \Delta \lambda (\sin \varphi_2 - \sin \varphi_1)} \sum_{\ell=2}^{\ell_{MAX}} (\ell-1) [\Delta \lambda \bar{C}_{\ell 0} \int_{\varphi_1}^{\varphi_2} \bar{P}_{\ell 0}(\sin \bar{\varphi}) \cos \varphi d \varphi$$

$$+ \sum_{m=1}^{\ell} \frac{1}{m} [\bar{C}_{\ell m} (\sin m \lambda_2 - \sin m \lambda_1) - \bar{S}_{\ell m} (\cos m \lambda_2 - \cos m \lambda_1)]$$

$$\cdot \int_{\varphi_1}^{\varphi_2} \bar{P}_{\ell m}(\sin \bar{\varphi}) \cos \varphi d \varphi$$

A similar equation to (35) follows from equation (4).

We proposed to test the prediction method using an ellipsoidal model ($\Delta g_R = N_R = 0$) and a reference model defined by the GEM 9 coefficients taken to degree 20. This test used the adjusted data in the Philippines regional adjustment for the prediction of $1^\circ \times 1^\circ$ anomalies using the ellipsoidal model and the GEM 9 model. The predicted anomalies were compared with a set of terrestrial anomalies estimated from a contour map of Watts (1976). The results are given in Table 12.

Table 12

$1^\circ \times 1^\circ$ Anomaly Comparisons in the
Philippines Regional Adjustment

	Ellipsoidal Ref.	GEM 9 Ref.
Mean Diff. (Alt. - Terr.)	2.3 mgals	1.5 mgals
RMS Diff. (Alt. - Terr.)	± 13.4	± 12.3
RMS Alt. Std. Dev.	± 10.4	± 7.8

We see from these values that the influence of the reference field in the final predicted values is small with the use of the GEM 9 model yielding slightly better results than the ellipsoidal mode. The main difference is the 25% reduction of the predicted standard error in going to the GEM 9 field, but the predicted standard deviation does not include an error contribution from the potential coefficients. Because of these tests we decided to use in all further predictions the GEM 9 potential coefficients as the reference field.

Mean Anomaly and Undulation Production Results

Using the geoid undulations (or sea surface heights) obtained from the regional adjustments, and using the procedures outlined in the previous paragraphs, 301 5° equal area mean anomalies and undulations and 9995 $1^\circ \times 1^\circ$ mean anomalies and undulations were computed. The 5° equal area blocks division used is that described in Rapp (1977). This scheme, originally suggested by Kaula, was used because recent estimates of the anomalies in these blocks were available from terrestrial gravity sources, Rapp (Ibid.).

The areas in which the mean values were determined are shown in Figure 10. These areas were chosen so that they maximized the available altimeter data. In addition, emphasis was given to the estimation of anomalies in areas where little or no terrestrial data was available. Such areas are apparent from Figure 11 taken from Rapp (1977), which reflected the status of the available gravity data as of August 1976.

We report these results in the following way:

1. In Appendix A we give a listing of the 5° mean anomalies and undulations, and their predicted accuracy.
2. In Appendix B we give maps, containing shoreline plots, where all $1^\circ \times 1^\circ$ anomalies and their accuracy are shown.
3. In Appendix C we give, for a single geographic area, maps showing the $1^\circ \times 1^\circ$ mean geoid undulations and their accuracy. Only this area was plotted for space reasons in this report.
4. A separate listing of all the $1^\circ \times 1^\circ$ anomalies, undulations and their accuracy which is available from the author.

Five Degree Mean Anomaly Comparisons

The predicted 5° equal area anomalies from altimeter data have been compared to the corresponding terrestrial values as given in Rapp (1977). These comparisons have been carried out with several subsets of the 5° anomalies. These subsets are:

1. The seven anomalies (287, 342, 343, 402, 403, 465, 466) that lie off the east coast of the United States in an area of dense altimeter coverage and good terrestrial gravity data.
2. The 153 anomalies in which the terrestrial standard deviation was better than ± 6 mgals.
3. All 301 5° anomalies independent of the accuracy of the terrestrial estimates.

The results of these comparisons are given in Table 13.

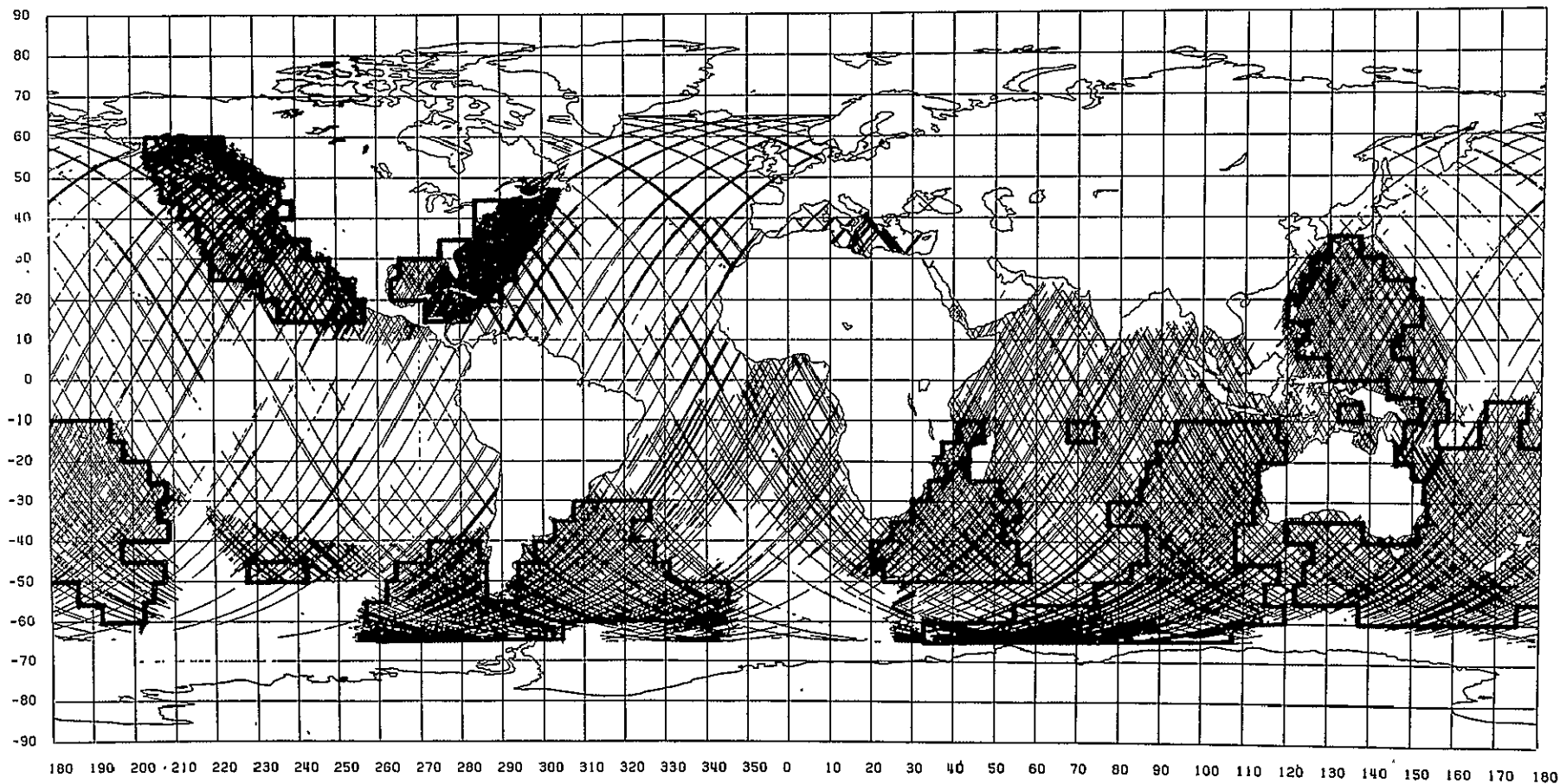


Figure 10

Location of Areas Where 5° Equal Area and 1°x1° Mean Anomalies
and Undulations Have Been Computed

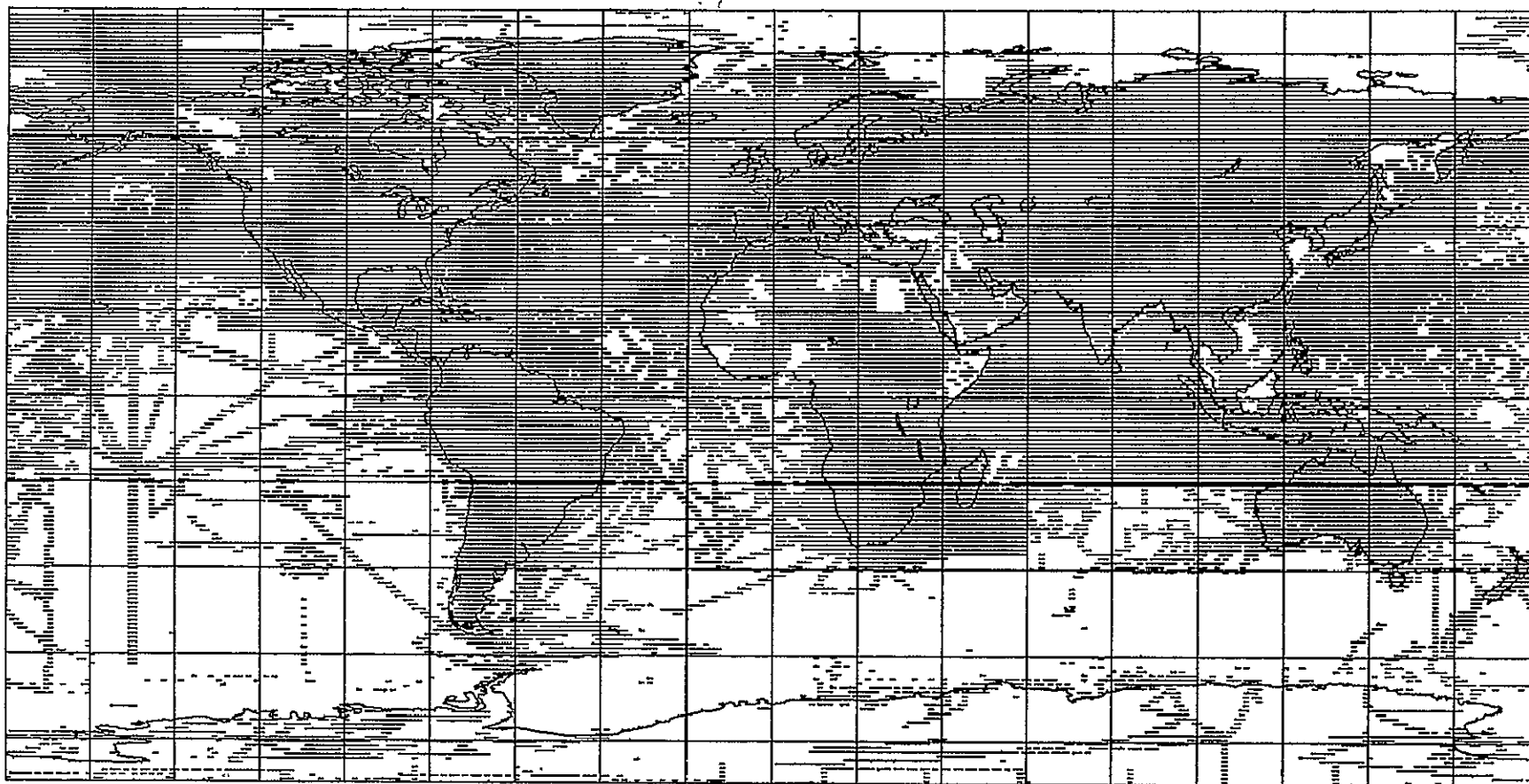


Figure 11

Location of the 1°x 1° Anomalies on the August 1976 Data Tape (Rapp, 1977)

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Table 13

Comparison of Altimeter Derived 5° Equal Area
Anomalies with Corresponding Terrestrial Values
(mgals)

Quantity	Subset*		
	One	Two	Three
Mean Diff. (GEM 9 - Terr.)	1.3	1.5	1.7
Mean Diff. (Alt. - Terr.)	0.2	1.2	1.8
RMS Diff. (GEM 9 - Terr.)	6.9	10.0	12.3
RMS Diff. (Alt. - Terr.)	1.7	6.6	11.1
RMS GEM 9 Anomaly	22.6	14.8	13.8
RMS Alt. Anomaly	23.9	16.3	14.8
RMS Terr. Anomaly	24.3	17.8	15.9
RMS Terr. Std. Error	2.3	3.6	9.7
RMS Alt. Std. Error	2.5	2.6	2.5
Number of Blocks	7	153	301

* see text for description of subsets

Considering the comparisons with subset one, we see excellent agreement of the altimeter derived 5° anomalies with the terrestrial data. The smaller root mean square difference (± 1.7) mgals with the altimeter anomalies than with the GEM 9 anomalies (± 6.9 mgals) is a strong measure of the possibility of improving the GEM 9 gravity field.

The differences seen for subset two of the 5° equal area anomaly set reflect the somewhat poorer terrestrial gravity data in this area. The root mean square difference between the altimeter derived anomalies and the terrestrial data (of ± 6.6 mgals) is consistent with the standard deviations of the altimeter and terrestrial anomalies.

The comparisons with the full 301 value data set are shown for general purposes only as some of the terrestrial estimates are based on predictions using no $1^\circ \times 1^\circ$ terrestrial anomalies within the 5° block. In examining the differences of all the anomalies predicted, a number of large discrepancies are seen with the terrestrial data. Specifically, we found 18 values where the differences were greater than 20 mgals (in absolute value). I give in Table 14 the blocks and pertinent information having anomaly differences greater than 30 mgals.

Table 14

5° Blocks in Which the Difference Between the
Altimeter Derived Anomaly and the Terrestrial Anomaly
is Greater Than 30 mgals (in Absolute Value)

Block	Δg_{ALT}	Δg_{TERR}	Difference
1363	1.3 ± 2.5 mgals	67.1 ± 7.8 mgals	-65.8 mgals
1209	17.1 ± 2.5	-34.4 ± 6.3	51.5
1269	11.0 ± 2.5	-35.6 ± 10.5	46.6
1272	15.2 ± 2.4	-24.1 ± 12.0	39.3
1332	8.4 ± 2.5	-26.3 ± 10.1	34.7
1386	9.5 ± 2.5	-22.4 ± 12.8	31.9

In most cases these discrepancies are much larger than expected considering the given standard deviations. In the case of block 1363, the positive terrestrial anomaly estimate is based on some $1^\circ \times 1^\circ$ anomalies on the order of 100 mgals. Such magnitudes are not in agreement with the altimeter derived values. To explain the large discrepancies shown in Table 14, a more detailed examination of the terrestrial gravity data in these areas is needed.

One Degree by One Degree Anomaly Comparisons

We have compared the predicted $1^\circ \times 1^\circ$ anomalies with existing terrestrial gravity data in two areas: the area (in 8 5° equal area blocks) off the east coast of the United States having dense altimeter coverage and good gravity data; and the area (in 20 5° equal area blocks) in the Philippines regional adjustment area where a new gravity anomaly map by Watts (1976) is available. In addition, the anomaly variations in the Philippines area is much greater than in the U. S. calibration area. The results of these comparisons are given in Table 15. The increased discrepancy in the Philippines Area (over the calibration area) is due to the much larger anomaly variations that exist in the Philippines Area. In both areas the predicted standard deviations of the altimeter derived anomalies (on the order of ± 7 mgals) appears to be consistent with the root mean square differences between the altimeter and terrestrial anomalies.

In addition to the above comparisons, we also compared all the $1^\circ \times 1^\circ$ altimeter derived anomalies to the anomalies (when available) on the August 76 tape (Rapp, 1977). We found that there were 5119 altimeter anomalies where there were no terrestrial estimates available. In addition, we found a number of blocks where the discrepancies were quite large between the two anomaly types. Specifically, we found 157 blocks where the absolute anomaly difference was greater than 50 mgals, and 10 blocks where the difference was greater than 100

Table 15

Comparison of Altimeter Derived $1^\circ \times 1^\circ$ Anomalies
with Corresponding Terrestrial Values
(mgals)

	Calibration Area	Philippines Area
Mean Diff. (GEM 9 - Terr.)	1.8	-0.4
Mean Diff. (Alt. - Terr.)	1.3	0.1
RMS Diff. (GEM 9 - Terr.)	± 16.3	± 30.8
RMS Diff. (Alt. - Terr.)	± 8.0	± 15.8
RMS Alt. Anomaly	26.1	31.0
RMS Terr. Anomaly	28.2	33.4
RMS Terr. Std. Error	12.4	10.7
RMS Alt. Std. Error	8.3	7.3
Number of Blocks	245	520

Table 16

Selected $1^\circ \times 1^\circ$ Mean Anomalies Across
the Philippine and Mariana Trench
(mgals)

Philippine Trench					Mariana Trench				
ϕ°	λ°	$\Delta g_{\text{GEM 9}}$	Δg_{ALT}	$\Delta g_{\text{(TERR)}}$	ϕ°	λ°	$\Delta g_{\text{GEM 9}}$	Δg_{ALT}	$\Delta g_{\text{(TERR)}}$
11	123	35	59 ± 11	45 ± 10	14	142	7	39 ± 10	27 ± 10
11	124	33	85 ± 9	70 ± 12	14	143	7	47 ± 7	52 ± 10
11	125	31	140 ± 9	153 ± 20	14	144	6	102 ± 6	92 ± 20
11	126	29	-97 ± 6	-107 ± 25	14	145	6	1 ± 8	40 ± 15
11	127	27	21 ± 6	31 ± 10	14	146	5	-135 ± 7	-148 ± 25
11	128	25	37 ± 6	43 ± 10	14	147	5	-47 ± 7	-38 ± 15
11	129	23	31 ± 6	38 ± 10	14	148	5	18 ± 7	22 ± 12

mgals. The largest difference found was 169 mgals at a block whose northwest corner was $-32^\circ (\phi)$, $181^\circ (\lambda)$. Here the altimeter anomaly was -16 ± 6 mgals while the terrestrial estimate was 153 ± 19 mgals. A complete list of the locations of these large discrepancy blocks is available.

The success of the 1° predictions in reliable ground truth areas suggests that bad or questionable terrestrial data may be screened by comparisons with the altimeter derived anomalies.

To demonstrate the ability of the altimeter derived anomalies to reproduce the rapid variations of the anomaly field in certain cases, I give in Table 16, $1^\circ \times 1^\circ$ mean anomalies across a portion of the Philippine Trench and a portion of the Mariana Trench from GEM 9 potential coefficients, from altimeter data and as estimated from the Watts (1976) map.

From this table we can see the rapid variation of the anomaly that is implied by the altimeter data and is not seen in the low degree anomalies derived from a set of potential coefficients given to degree 20. We also see a good agreement between the altimeter and terrestrial data.

Preliminary computations have shown that it is possible to produce essentially a continuous anomaly profile from the altimeter data that agrees quite well with estimated values based on terrestrial data. With such a procedure, we have seen anomaly changes of 450 mgals in 130 km.

Summary and Conclusions

In this report we have described the methods used to determine mean anomalies and mean undulations from the Geos-3 altimeter data available to us by the end of September, 1977, without having a complete set of precise orbits. The editing of the data was extensive to remove questionable data, although no filtering of the data was carried out. An adjustment process was carried out to remove orbit error and an altimeter bias. This adjustment was carried out first in a primary net, and then in regional nets. This adjustment used a very simple first degree polynomial in time for the orbit and bias error (for sufficiently long arcs) and introduced cross-over observation equations. After the adjustment, a set of adjusted geoid undulations were available that were used to produce geoid undulation maps (of about ± 1 m accuracy) and mean gravity anomalies and undulations in 301 5° equal area blocks and 9995 $1^\circ \times 1^\circ$ blocks. The predicted accuracy of a 5° block was ± 3 mgals while it was ± 6 mgals for $1^\circ \times 1^\circ$ anomalies. These accuracies indicate a significant improvement (by a factor of roughly 2) over the accuracies that could be obtained from the GEM 9 potential coefficients themselves. Values were predicted only where the altimeter data was of sufficient density to yield best results. Other areas could also be predicted with somewhat poorer accuracies. 5119 $1^\circ \times 1^\circ$ anomaly estimates took place in areas where no terrestrial data had previously been available. Where terrestrial data was available, comparisons with the altimeter derived data were made. For the most part, excellent agreement was found between the two sets of anomalies indicating the predicted standard deviations are reasonable.

In the future, more altimeter data is needed to fill in the gaps obvious in Figure 1. When such data is available, additional anomaly estimations can be made. Because of the homogeneity of the altimeter data, and because of its distribution, it would appear that anomalies derived from satellite altimeter may be more reliable, as a whole, than those derived from ship board data.

We finally note that additional work needs to be done to improve the orbit error model, and to investigate the errors caused by sea surface topography.

The gravity anomalies derived from the altimeter data appear to be an excellent source of information for improving our knowledge of the structure of the earth.

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Appendix A

This appendix contains a listing of the 5° equal area free-air anomalies and undulations as derived from Geos-3 altimeter data. These values refer to an ellipsoid whose flattening is 1/298.257 and whose equatorial radius is theoretically unknown, being actually the equatorial radius of the general terrestrial ellipsoid.

SEQ	LAT	LONG	ANOM	S.D.	UND	S.D.	SEQ	LAT	LONG	ANOM	S.D.	UND	S.D.
134	60	55 212 203	15.0	2.9	12.4	0.2	135	60	55 222 212	14.0	2.7	8.3	0.1
176	55	50 213 205	23.6	2.5	7.2	0.1	177	55	50 221 213	8.8	2.5	-1.1	0.1
178	55	50 229 221	-2.7	2.6	-9.4	0.1	223	50	45 213 206	3.0	2.5	-5.8	0.1
224	50	45 220 213	-4.2	2.5	-13.2	0.1	225	50	45 228 220	-14.8	2.5	-23.2	0.1
226	50	45 235 228	-6.7	2.7	-21.7	0.1	275	45	40 217 211	-5.9	2.5	-17.1	0.1
276	45	40 224 217	-12.2	2.5	-26.5	0.1	277	45	40 231 224	-12.2	2.5	-29.8	0.1
278	45	40 238 231	-7.6	3.0	-28.3	0.4	286	45	40 292 285	0.6	3.9	-29.2	0.8
287	45	40 299 292	-6.6	2.5	-24.7	0.1	331	40	35 221 215	-21.1	2.5	-29.7	0.1
332	40	35 227 221	-21.9	2.5	-34.8	0.1	333	40	35 234 227	-24.1	2.5	-44.0	0.1
342	40	35 291 284	-23.3	2.7	-45.9	0.1	343	40	35 297 291	-23.4	2.4	-36.8	0.1
391	35	30 224 218	-9.1	2.5	-29.8	0.1	392	35	30 230 224	-14.1	2.5	-36.4	0.1
393	35	30 236 230	-15.0	2.5	-40.4	0.1	394	35	30 242 236	-13.9	2.6	-39.5	0.1
401	35	30 283 277	-3.9	3.6	-33.7	0.6	402	35	30 289 283	-32.5	2.5	-45.8	0.1
403	35	30 295 289	-23.9	2.5	-44.8	0.1	437	30	25 129 124	18.6	2.5	23.1	0.1
438	30	25 135 129	-13.8	2.5	-2.7	0.1	439	30	25 141 135	20.5	2.5	40.4	0.1
454	30	25 225 219	-5.4	2.6	-27.9	0.1	455	30	25 231 225	-12.0	2.5	-36.4	0.1
456	30	25 236 231	-16.3	2.4	-35.7	0.1	457	30	25 242 236	-18.3	2.5	-44.2	0.1
458	30	25 248 242	-13.7	2.7	-39.4	0.1	462	30	25 270 264	-12.0	2.9	-26.7	0.1
463	30	25 276 270	-3.3	2.7	-26.1	0.1	464	30	25 281 276	5.8	2.6	-21.8	0.2
465	30	25 287 281	-17.8	2.5	-39.8	0.1	466	30	25 293 287	-30.2	2.5	-49.2	0.1
502	25	20 129 124	3.4	2.5	30.0	0.1	503	25	20 134 129	9.1	2.5	37.2	0.1
504	25	20 140 134	14.4	2.5	51.5	0.1	505	25	20 145 140	14.6	2.5	43.1	0.1
506	25	20 150 145	0.9	2.6	34.9	0.1	522	25	20 236 231	-16.2	2.5	-42.5	0.1
523	25	20 242 236	-26.6	2.5	-55.5	0.1	524	25	20 247 242	-19.3	2.5	-42.9	0.1
525	25	20 253 247	-9.4	2.6	-39.8	0.1	528	25	20 269 263	-20.7	2.6	-25.8	0.1
529	25	20 274 269	6.6	2.6	-16.9	0.2	530	25	20 279 274	-5.4	2.4	-19.9	0.1
531	25	20 285 279	8.1	2.5	-31.1	0.1	532	25	20 290 285	-32.5	2.6	-42.4	0.1
569	20	15 125 120	16.0	2.9	36.4	0.2	570	20	15 130 125	13.1	2.5	42.0	0.1
571	20	15 136 130	5.8	2.5	53.8	0.1	572	20	15 141 136	13.9	2.4	49.4	0.1
573	20	15 146 141	31.2	2.5	50.7	0.1	574	20	15 151 146	-4.5	2.4	39.7	0.1
591	20	15 240 235	-20.4	2.6	-44.3	0.1	592	20	15 245 240	-20.7	2.5	-44.0	0.1
593	20	15 250 245	-12.4	2.6	-37.0	0.1	594	20	15 256 250	-4.3	2.6	-31.0	0.1
598	20	15 277 271	13.2	2.9	-7.2	0.1	599	20	15 282 277	12.2	2.5	-10.2	0.1
639	15	10 129 123	29.3	2.6	64.2	0.1	640	15	10 134 129	9.9	2.4	54.1	0.1
641	15	10 139 134	11.8	2.4	55.1	0.1	642	15	10 144 139	-4.4	2.5	51.4	0.1
643	15	10 149 144	-10.8	2.5	45.4	0.1	710	10	5 132 127	10.0	2.5	62.5	0.1
711	10	5 137 132	20.0	2.5	64.4	0.1	712	10	5 142 137	21.9	2.4	63.4	0.1
713	10	5 147 142	19.3	2.4	60.3	0.1	782	5	0 135 130	37.9	2.5	72.9	0.1
783	5	0 140 135	24.7	2.5	70.7	0.1	784	5	0 145 140	19.2	2.4	68.5	0.1
785	5	0 150 145	12.3	2.4	63.4	0.1	857	0	-5 150 145	44.7	2.5	75.5	0.1
858	0	-5 155 150	21.0	2.5	65.9	0.1	926	-5	-10 137 132	21.5	2.5	63.0	0.1
930	-5	-10 157 152	20.1	2.5	67.6	0.1	934	-5	-10 177 172	-5.2	2.4	37.1	0.1
979	-10	-15 46 41	-14.1	2.5	-25.4	0.1	984	-10	-15 72 67	-4.5	2.5	-49.0	0.1
989	-10	-15 98 93	-13.7	2.5	-45.3	0.1	990	-10	-15 103 98	-9.2	2.5	-30.3	0.1
991	-10	-15 108 103	1.2	2.5	-14.5	0.1	992	-10	-15 113 108	-1.0	2.5	-1.6	0.1
993	-10	-15 118 113	-14.9	2.4	9.2	0.1	1000	-10	-15 154 149	11.2	2.5	67.3	0.1
1003	-10	-15 170 165	11.8	2.5	58.4	0.1	1004	-10	-15 175 170	22.3	2.5	55.6	0.1
1005	-10	-15 180 175	12.2	2.5	46.8	0.1	1006	-10	-15 185 180	10.5	2.5	38.5	0.1
1007	-10	-15 190 185	3.6	2.5	28.6	0.1	1008	-10	-15 195 190	-2.2	2.5	19.5	0.1
1048	-15	-20 42 37	-13.7	3.0	-12.6	0.3	1058	-15	-20 94 89	-22.4	2.5	-51.4	0.1
1059	-15	-20 99 94	-22.6	2.5	-46.4	0.1	1060	-15	-20 104 99	-26.0	2.4	-39.0	0.1
1061	-15	-20 110 104	-25.9	2.5	-31.3	0.1	1062	-15	-20 115 110	-17.7	2.4	-12.8	0.1
1063	-15	-20 120 115	-13.4	2.7	1.4	0.1	1069	-15	-20 151 146	18.9	2.9	61.4	0.2
1070	-15	-20 157 151	19.5	2.6	73.7	0.1	1072	-15	-20 167 162	17.9	2.5	60.4	0.1

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SEQ	LAT	LONG	ANOM	S.D.	UND	S.D.	SEQ	LAT	LONG	ANOM	S.D.	UND	S.D.				
1073	-15	-20	172	167	31.4	2.5	63.7	0.1	1074	-15	-20	177	172	32.4	2.5	61.2	0.1
1075	-15	-20	183	177	25.9	2.5	62.0	0.1	1076	-15	-20	188	183	22.5	2.5	41.6	0.1
1077	-15	-20	193	188	6.7	2.4	25.4	0.1	1078	-15	-20	198	193	-3.6	2.4	15.4	0.1
1117	-20	-25	43	38	-1.3	2.5	-0.6	0.1	1126	-20	-25	91	86	-7.1	2.5	-40.2	0.1
1127	-20	-25	97	91	-20.3	2.5	-53.0	0.1	1128	-20	-25	102	97	-25.8	2.4	-43.3	0.1
1129	-20	-25	107	102	-16.5	2.4	-35.9	0.1	1130	-20	-25	113	107	-22.5	2.5	-33.1	0.1
1138	-20	-25	156	150	18.7	2.7	62.4	0.1	1139	-20	-25	161	156	11.2	2.4	52.1	0.1
1140	-20	-25	167	161	18.4	2.5	65.9	0.1	1141	-20	-25	172	167	17.7	2.4	56.8	0.1
1142	-20	-25	177	172	24.4	2.5	56.5	0.1	1143	-20	-25	183	177	28.7	2.5	62.0	0.1
1144	-20	-25	188	183	11.3	2.4	38.6	0.1	1145	-20	-25	193	188	5.1	2.4	25.1	0.1
1146	-20	-25	199	193	-1.5	2.5	16.9	0.1	1147	-20	-25	204	199	6.2	2.5	9.1	0.1
1183	-25	-30	39	34	0.1	2.5	11.5	0.1	1184	-25	-30	45	39	-7.6	2.5	9.7	0.1
1185	-25	-30	51	45	5.7	2.5	10.6	0.1	1192	-25	-30	90	84	-0.8	2.5	-26.3	0.1
1193	-25	-30	96	90	-13.6	2.5	-35.2	0.1	1194	-25	-30	101	96	-10.0	2.4	-31.2	0.1
1195	-25	-30	107	101	-11.5	2.5	-37.2	0.1	1196	-25	-30	113	107	-24.0	2.5	-34.1	0.1
1204	-25	-30	158	152	7.9	2.8	39.5	0.2	1205	-25	-30	163	158	9.2	2.4	35.1	0.1
1206	-25	-30	169	163	10.1	2.5	45.6	0.1	1207	-25	-30	174	169	18.8	2.4	41.8	0.1
1208	-25	-30	180	174	18.0	2.5	48.7	0.1	1209	-25	-30	186	180	17.1	2.5	40.2	0.1
1210	-25	-30	191	186	17.8	2.4	24.5	0.1	1211	-25	-30	197	191	0.6	2.5	16.6	0.1
1212	-25	-30	203	197	-0.7	2.5	8.0	0.1	1213	-25	-30	208	203	-2.7	2.5	1.7	0.1
1246	-30	-35	35	30	5.5	2.5	22.9	0.1	1247	-30	-35	41	35	0.4	2.5	22.5	0.1
1248	-30	-35	47	41	22.6	2.5	26.3	0.1	1249	-30	-35	53	47	7.1	2.5	23.5	0.1
1254	-30	-35	83	77	11.6	2.5	-1.8	0.1	1255	-30	-35	89	83	6.6	2.5	-12.0	0.1
1256	-30	-35	94	89	-3.0	2.4	-18.3	0.1	1257	-30	-35	100	94	-10.8	2.5	-30.4	0.1
1258	-30	-35	106	100	-23.9	2.5	-37.4	0.1	1259	-30	-35	112	106	-21.3	2.5	-38.1	0.1
1267	-30	-35	159	153	-7.3	2.5	24.7	0.1	1268	-30	-35	165	159	8.4	2.5	30.6	0.1
1269	-30	-35	171	165	11.0	2.5	36.4	0.1	1270	-30	-35	177	171	23.8	2.5	41.9	0.1
1271	-30	-35	183	177	17.9	2.4	37.3	0.1	1272	-30	-35	189	183	15.2	2.4	26.9	0.1
1273	-30	-35	195	189	1.7	2.5	17.3	0.1	1274	-30	-35	201	195	4.1	2.5	9.4	0.1
1275	-30	-35	207	201	2.1	2.5	2.8	0.1	1293	-30	-35	313	307	1.9	2.7	3.8	0.1
1294	-30	-35	319	313	-15.0	2.5	-5.7	0.1	1295	-30	-35	325	319	-8.7	2.5	-4.0	0.1
1306	-35	-40	32	25	7.5	2.5	37.2	0.1	1307	-35	-40	38	32	5.5	2.5	31.7	0.1
1308	-35	-40	44	38	11.4	2.5	34.1	0.1	1309	-35	-40	51	44	34.0	2.5	44.8	0.1
1316	-35	-40	95	88	1.8	2.5	-12.6	0.1	1317	-35	-40	101	95	-8.7	2.5	-22.7	0.1
1318	-35	-40	107	101	-16.2	2.4	-31.3	0.1	1321	-35	-40	126	120	-32.3	2.7	-33.3	0.1
1322	-35	-40	133	126	-34.7	2.6	-32.1	0.1	1323	-35	-40	139	133	-22.2	2.6	-15.7	0.1
1326	-35	-40	158	152	-4.1	2.4	10.1	0.1	1327	-35	-40	164	158	-7.8	2.4	14.5	0.1
1328	-35	-40	171	164	15.1	2.5	27.4	0.1	1329	-35	-40	177	171	24.4	2.7	29.2	0.2
1330	-35	-40	183	177	3.4	2.5	23.9	0.1	1331	-35	-40	189	183	8.9	2.5	18.6	0.1
1332	-35	-40	196	189	8.4	2.5	13.3	0.1	1333	-35	-40	202	196	8.1	2.5	5.6	0.1
1334	-35	-40	208	202	4.8	2.7	0.2	0.1	1350	-35	-40	309	303	4.6	2.6	7.7	0.1
1351	-35	-40	316	309	-16.6	2.5	-3.5	0.1	1352	-35	-40	322	316	-14.7	2.5	-5.4	0.1
1362	-40	-45	27	20	8.3	2.7	33.8	0.1	1363	-40	-45	34	27	1.3	2.5	35.0	0.1
1364	-40	-45	41	34	22.8	2.5	41.6	0.1	1365	-40	-45	48	41	21.7	2.5	43.9	0.1
1366	-40	-45	54	48	14.7	2.4	35.8	0.1	1372	-40	-45	95	88	11.7	2.5	6.9	0.1
1373	-40	-45	102	95	0.3	2.5	-12.0	0.1	1374	-40	-45	109	102	-8.1	2.5	-22.7	0.1
1377	-40	-45	129	122	-13.6	2.5	-27.8	0.1	1378	-40	-45	136	129	-13.5	2.5	-22.7	0.1
1379	-40	-45	143	136	-16.4	2.5	-15.7	0.1	1380	-40	-45	149	143	4.3	2.5	-5.0	0.2
1381	-40	-45	156	149	-14.7	2.5	-4.3	0.1	1382	-40	-45	163	156	-9.3	2.5	0.2	0.1
1383	-40	-45	170	163	-2.9	2.6	7.5	0.1	1384	-40	-45	177	170	12.4	2.6	13.2	0.1
1385	-40	-45	183	177	21.7	2.5	12.6	0.1	1386	-40	-45	190	183	9.5	2.5	7.3	0.1
1387	-40	-45	197	190	0.1	2.5	0.5	0.1	1399	-40	-45	278	272	4.0	2.4	3.1	0.1
1400	-40	-45	285	278	2.7	2.5	9.6	0.1	1403	-40	-45	306	299	-2.9	2.5	7.3	0.1
1404	-40	-45	312	306	-10.5	2.4	-0.7	0.1	1405	-40	-45	319	312	-15.4	2.5	-4.3	0.1

SEQ	LAT	LONG	ANOM	S.D.	UND	S.D.	SEQ	LAT	LONG	ANOM	S.D.	UND	S.D.
1406	-40	-45 326 319	-17.1	2.5	-3.3	0.1	1415	-45	-50 29 22	1.5	2.6	34.5	0.1
1416	-45	-50 37 29	21.6	2.5	47.3	0.1	1417	-45	-50 44 37	13.7	2.5	44.5	0.1
1418	-45	-50 51 44	20.3	2.5	45.5	0.1	1419	-45	-50 59 51	23.6	2.5	49.2	0.1
1423	-45	-50 88 81	18.3	2.5	19.0	0.1	1424	-45	-50 96 88	15.1	2.5	8.8	0.1
1425	-45	-50 103 96	6.9	2.4	-4.4	0.1	1426	-45	-50 110 103	0.0	2.5	-14.6	0.1
1427	-45	-50 118 110	-7.1	2.5	-25.2	0.1	1429	-45	-50 132 125	-4.7	2.4	-23.0	0.1
1430	-45	-50 140 132	-1.3	2.5	-21.4	0.1	1431	-45	-50 147 140	-7.0	2.5	-15.5	0.1
1432	-45	-50 154 147	-7.8	2.5	-13.1	0.1	1433	-45	-50 162 154	-10.9	2.5	-12.0	0.1
1434	-45	-50 169 162	3.9	2.5	-4.5	0.1	1435	-45	-50 176 169	3.1	2.5	-2.0	0.1
1436	-45	-50 184 176	-0.7	2.5	-5.8	0.1	1437	-45	-50 191 184	-10.0	2.5	-10.3	0.1
1438	-45	-50 198 191	-4.5	2.5	-11.6	0.1	1439	-45	-50 206 198	2.1	2.5	-12.8	0.1
1443	-45	-50 235 228	0.8	2.5	-13.6	0.1	1444	-45	-50 242 235	5.0	2.6	-11.0	0.1
1448	-45	-50 272 264	1.3	2.5	-4.1	0.1	1449	-45	-50 279 272	2.1	2.4	2.7	0.1
1450	-45	-50 287 279	9.3	2.9	12.5	0.3	1452	-45	-50 301 294	1.9	2.5	11.6	0.1
1453	-45	-50 309 301	-18.2	2.5	3.9	0.1	1454	-45	-50 316 309	-23.2	2.5	-1.8	0.1
1455	-45	-50 323 316	-17.6	2.4	-0.7	0.1	1456	-45	-50 331 323	-16.0	2.5	5.1	0.1
1470	-50	-55 82 74	26.5	2.5	30.5	0.1	1471	-50	-55 90 82	14.4	2.5	18.6	0.1
1472	-50	-55 98 90	11.3	2.5	7.9	0.1	1473	-50	-55 106 98	7.2	2.5	-3.2	0.1
1474	-50	-55 115 106	0.1	2.5	-15.6	0.1	1476	-50	-55 131 123	-4.9	2.5	-23.1	0.1
1477	-50	-55 139 131	-0.4	2.5	-21.3	0.1	1478	-50	-55 147 139	2.3	2.5	-18.9	0.1
1479	-50	-55 155 147	-3.4	2.5	-18.9	0.1	1480	-50	-55 164 155	-1.1	2.5	-20.3	0.1
1481	-50	-55 172 164	6.5	2.5	-16.9	0.1	1482	-50	-55 180 172	-14.5	2.5	-22.4	0.1
1484	-50	-55 196 188	-10.2	2.5	-24.0	0.1	1485	-50	-55 205 196	-5.1	2.6	-24.2	0.1
1493	-50	-55 270 262	-1.2	2.5	-7.2	0.1	1494	-50	-55 278 270	-1.1	2.5	-1.6	0.1
1495	-50	-55 286 278	-0.2	2.7	6.2	0.1	1497	-50	-55 303 295	3.0	2.4	13.0	0.1
1498	-50	-55 311 303	-6.9	2.5	8.6	0.1	1499	-50	-55 319 311	-1.4	2.5	7.9	0.1
1500	-50	-55 327 319	-0.2	2.5	10.4	0.1	1501	-50	-55 335 327	-1.7	2.5	13.7	0.1
1502	-50	-55 344 335	11.4	2.5	23.3	0.1	1511	-55	-60 65 55	9.8	2.5	38.9	0.1
1512	-55	-60 74 65	15.0	2.5	32.4	0.1	1513	-55	-60 83 74	21.4	2.4	27.1	0.1
1514	-55	-60 92 83	6.7	2.5	14.6	0.1	1515	-55	-60 102 92	8.0	2.5	3.3	0.1
1516	-55	-60 111 102	1.9	2.5	-8.6	0.1	1517	-55	-60 120 111	-4.9	2.9	-18.7	0.1
1520	-55	-60 148 138	-0.2	2.6	-29.2	0.1	1521	-55	-60 157 148	1.7	2.5	-26.3	0.1
1522	-55	-60 166 157	-20.2	2.5	-32.1	0.1	1523	-55	-60 175 166	-29.8	2.5	-38.3	0.1
1526	-55	-60 203 194	-10.0	2.7	-32.8	0.1	1533	-55	-60 268 258	-2.1	2.5	-13.4	0.1
1534	-55	-60 277 268	-2.6	2.4	-6.3	0.1	1535	-55	-60 286 277	-0.3	2.4	1.4	0.1
1536	-55	-60 295 286	11.0	2.5	11.6	0.1	1537	-55	-60 305 295	24.5	2.5	20.1	0.1
1538	-55	-60 314 305	17.6	2.5	18.5	0.1	1539	-55	-60 323 314	9.8	2.4	18.3	0.1
1540	-55	-60 332 323	30.0	2.5	21.0	0.1	1541	-55	-60 342 332	-2.5	2.5	19.2	0.1
1547	-60	-65 44 33	6.4	2.6	29.9	0.1	1548	-60	-65 55 44	2.7	2.6	31.2	0.1
1549	-60	-65 65 55	7.3	2.5	27.6	0.1	1550	-60	-65 76 65	8.7	2.6	26.2	0.1
1551	-60	-65 87 76	12.6	2.6	18.8	0.1	1552	-60	-65 98 87	-1.4	2.7	4.9	0.1
1553	-60	-65 109 98	-6.6	2.7	-8.2	0.1	1568	-60	-65 273 262	-8.8	2.6	-14.7	0.1
1569	-60	-65 284 273	-6.6	2.6	-5.8	0.1	1570	-60	-65 295 284	9.7	2.6	7.9	0.1
1571	-60	-65 305 295	28.3	2.8	17.4	0.1							

Appendix B

This appendix contains geographic area maps containing the $1^\circ \times 1^\circ$ mean free-air anomalies, and (on an adjacent map) the corresponding predicted accuracies, as estimated from the Geos-3 altimeter data. These maps have been prepared for 30 areas, approximately 30° in latitude extent and 20° in longitude extent. An index map for the individual maps is shown in Figure B₀. The individual maps follow, labeled Figures B₁ through B₃₀ with the anomaly map given first, followed by the standard deviation map.

The values given refer to an ellipsoid whose flattening is $1/298.257$ and whose equatorial radius is theoretically unknown, being actually the equatorial radius of the general terrestrial ellipsoid.

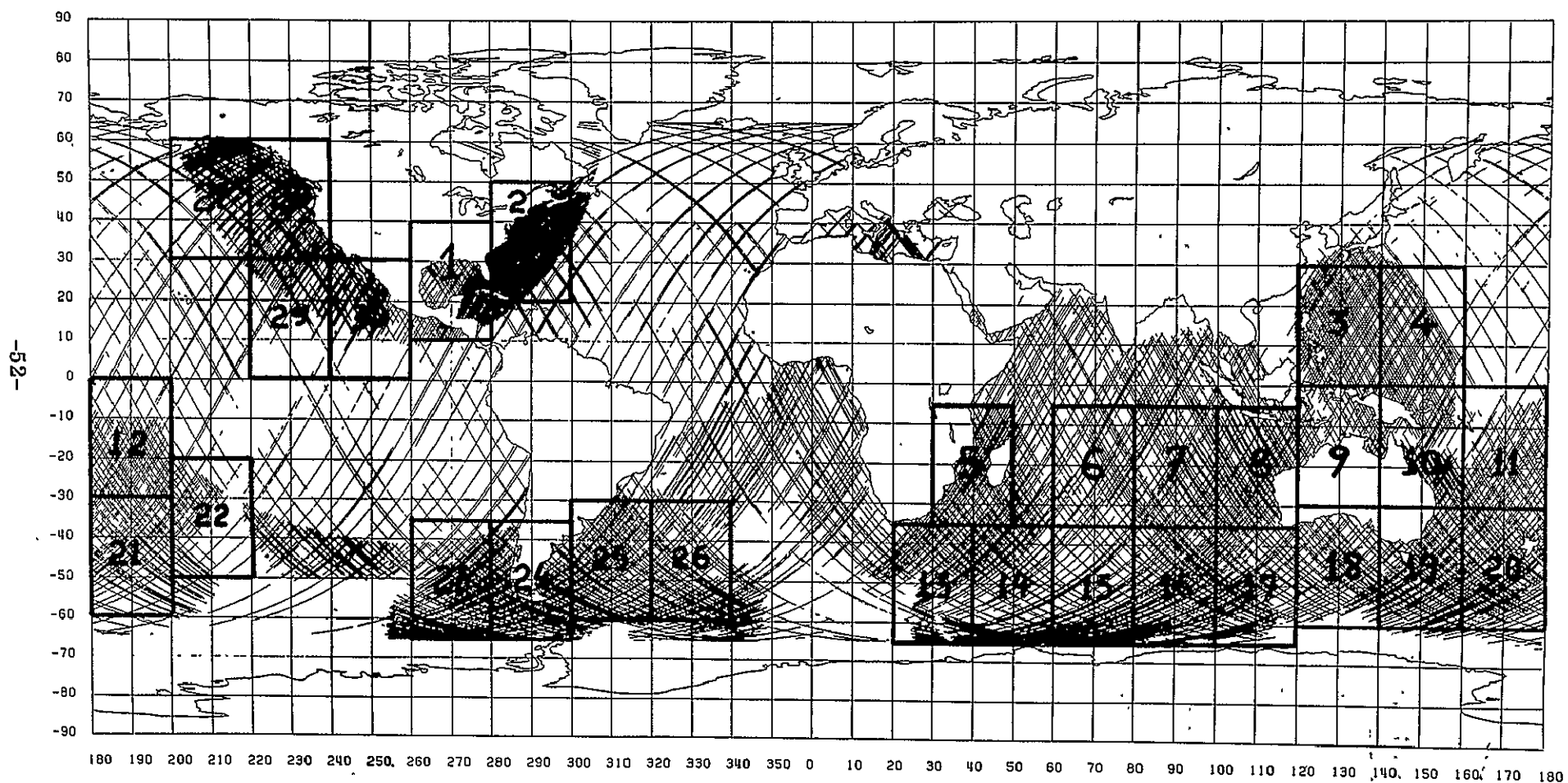
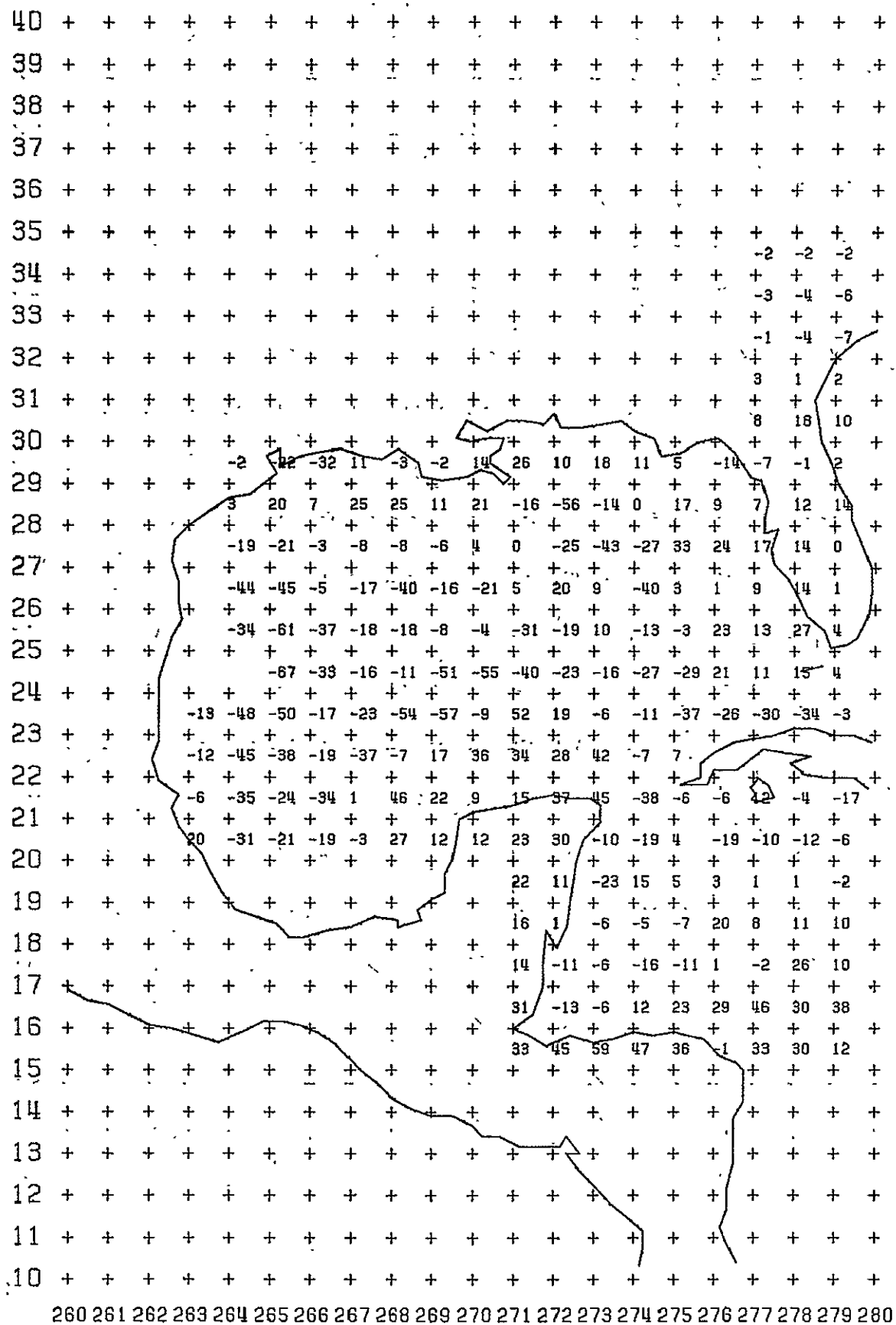


Figure B₀

Map Showing Areas Where 1° x 1° Anomalies and Their Accuracy are Given

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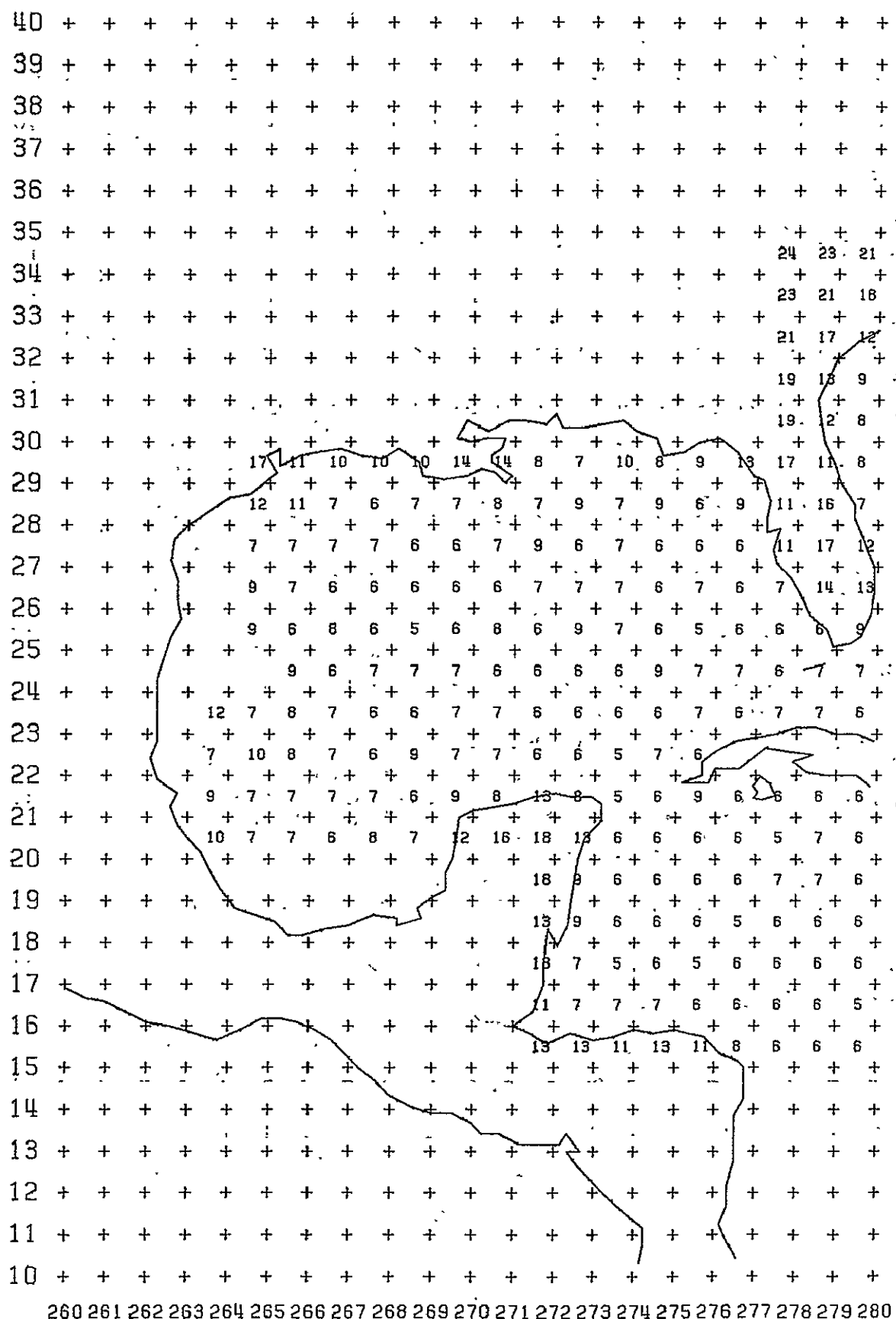
Figure B1A



1°x 1° Mean Free-Air Anomalies (mgals)

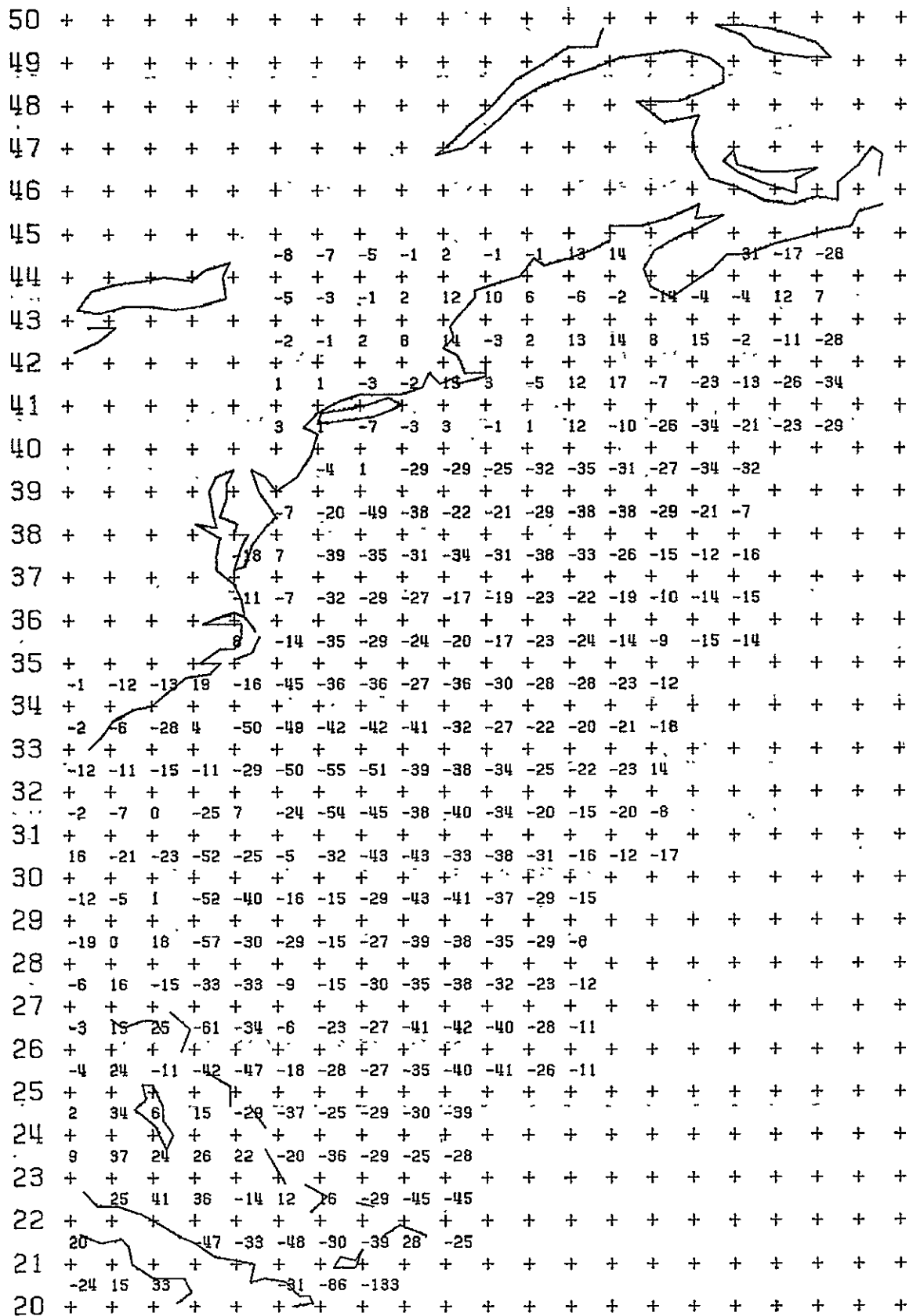
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Figure B1B



Accuracy of Predicted 1°x1° Mean Anomalies (mgals)

Figure B 2A

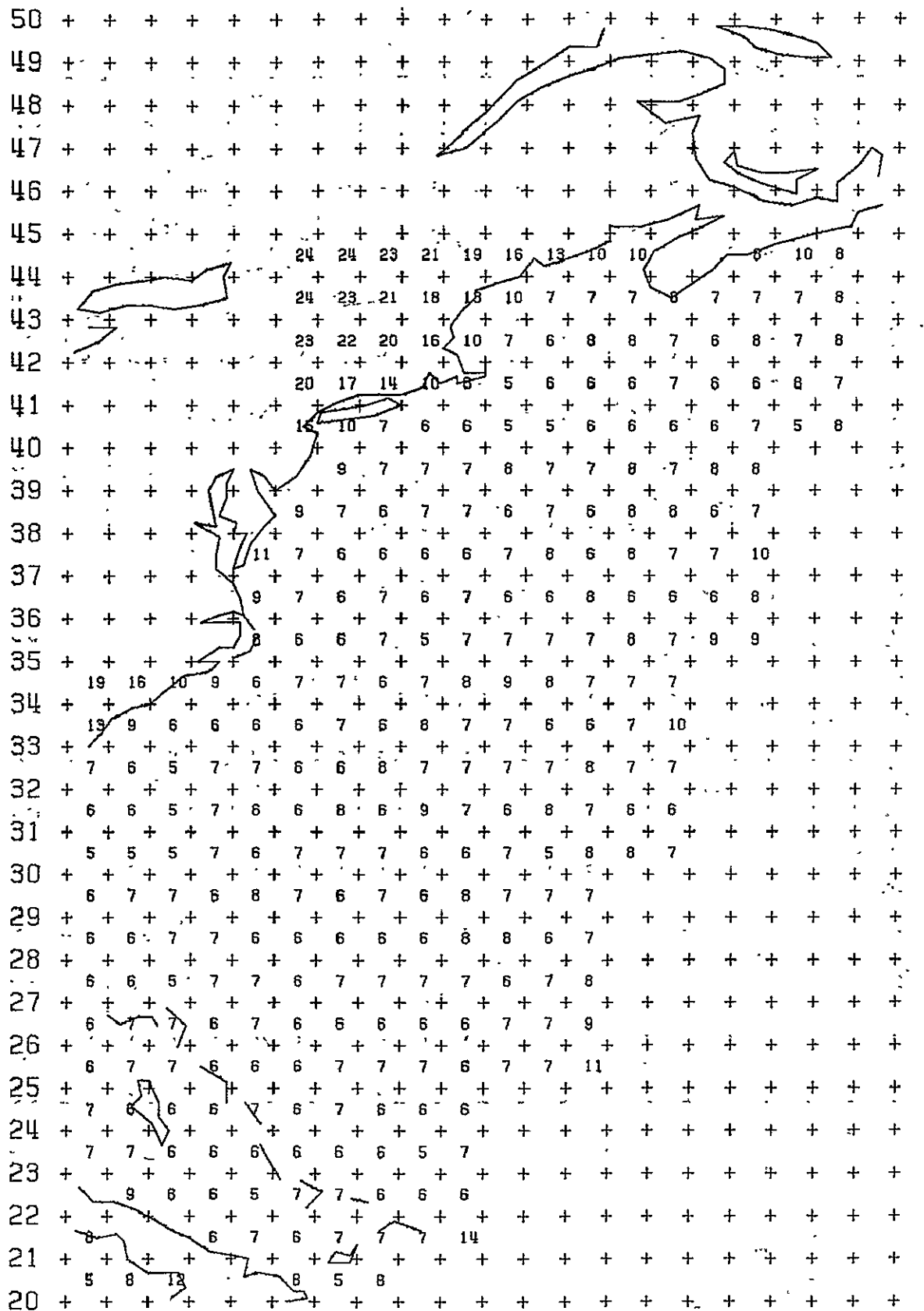


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280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300

1° x 1° Mean Free-Air Anomalies (mgals)

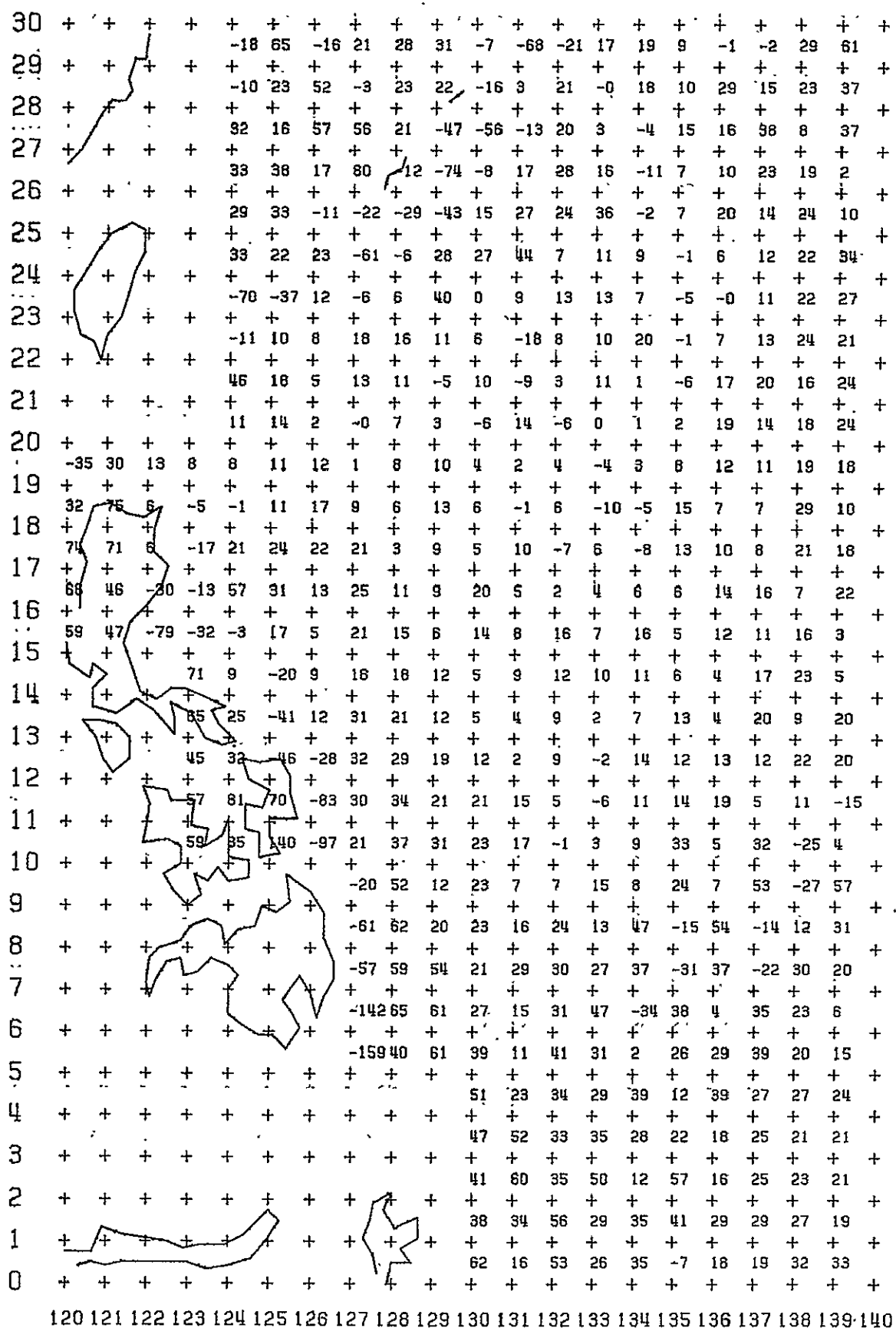
Figure B2B



280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300.

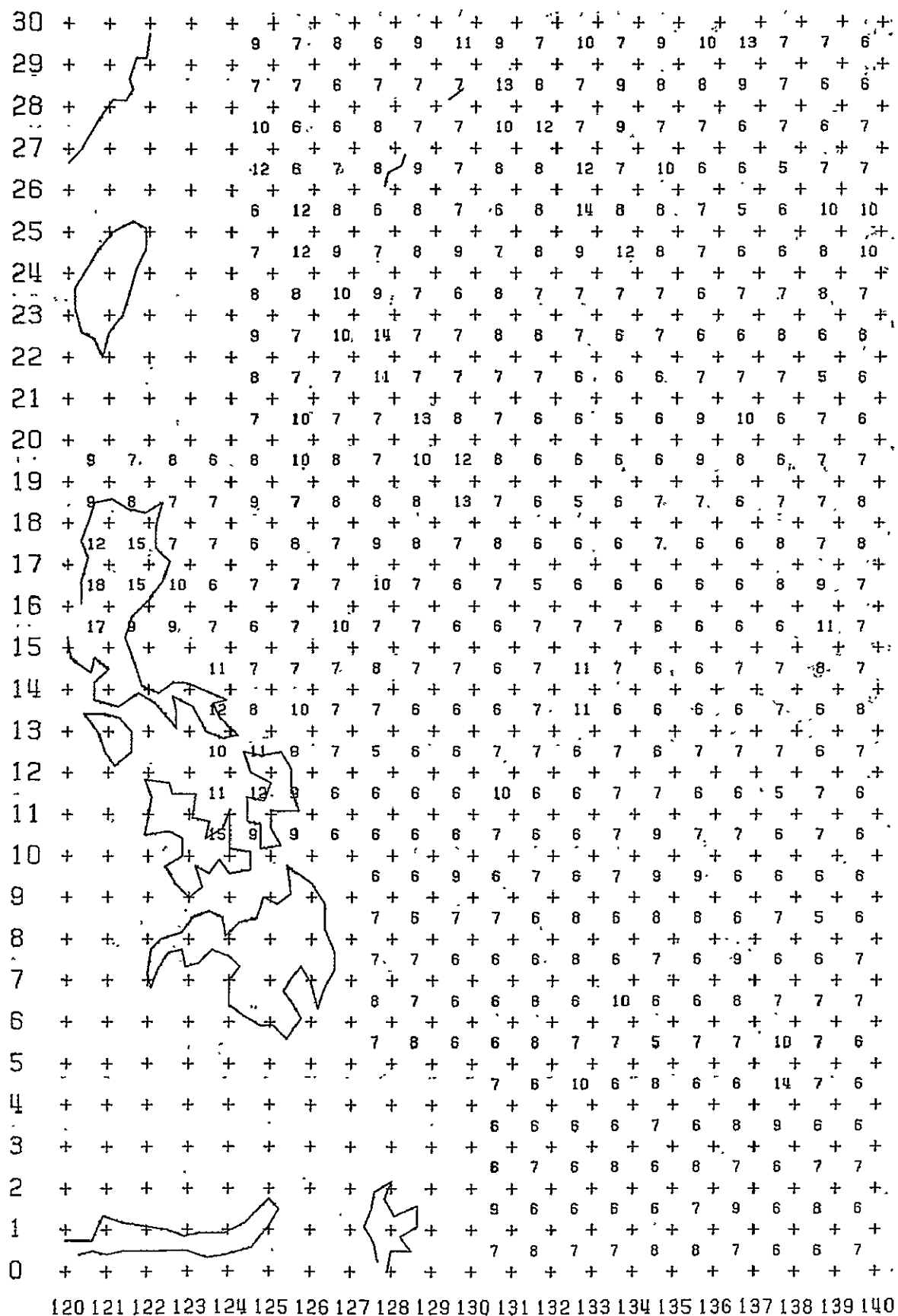
Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

Figure B 3A



1°x 1° Mean Free-Air Anomalies (mgals)

Figure B 3B



Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

Figure B 4A

30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
29	11	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
28	39	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
27	14	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
26	36	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
25	43	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
24	37	65	-3	-112	-7	59	21	3	-5	-4	+	+	+	+	+	+	+	+	+
23	31	53	16	-85	-92	-12	34	18	12	-3	+	+	+	+	+	+	+	+	+
22	40	49	46	30	-53	-119	-48	15	34	21	+	+	+	+	+	+	+	+	+
21	28	23	22	62	47	-41	-95	-7	23	13	+	+	+	+	+	+	+	+	+
20	19	26	40	36	53	56	-17	-7	33	31	+	+	+	+	+	+	+	+	+
19	17	13	29	18	46	36	-27	-80	1	26	43	+	+	+	+	+	+	+	+
18	18	8	20	42	34	30	-3	-80	-9	25	13	+	+	+	+	+	+	+	+
17	9	10	8	51	29	34	13	-106	-17	30	68	+	+	+	+	+	+	+	+
16	8	13	10	41	40	73	33	-81	-9	41	11	+	+	+	+	+	+	+	+
15	24	7	9	20	51	106	-9	-56	19	37	4	+	+	+	+	+	+	+	+
14	17	18	26	26	68	100	-44	-109	-7	+	+	+	+	+	+	+	+	+	+
13	6	28	39	47	102	1	-135	-47	18	+	+	+	+	+	+	+	+	+	+
12	13	14	57	59	-74	-156	-80	21	25	+	+	+	+	+	+	+	+	+	+
11	-10	-101	-161	-123	-97	2	19	7	-5	+	+	+	+	+	+	+	+	+	+
10	-10	-52	-30	-3	63	41	9	11	-2	+	+	+	+	+	+	+	+	+	+
9	58	43	25	-9	14	11	-1	+	+	+	+	+	+	+	+	+	+	+	+
8	16	34	45	19	9	30	19	+	+	+	+	+	+	+	+	+	+	+	+
7	24	29	27	34	14	23	30	+	+	+	+	+	+	+	+	+	+	+	+
6	14	15	29	22	21	18	14	+	+	+	+	+	+	+	+	+	+	+	+
5	8	21	24	14	16	16	15	+	+	+	+	+	+	+	+	+	+	+	+
4	1	24	20	13	22	11	10	22	19	-6	+	+	+	+	+	+	+	+	+
3	17	14	21	15	14	10	8	20	14	7	+	+	+	+	+	+	+	+	+
2	22	8	17	21	9	10	9	19	7	14	+	+	+	+	+	+	+	+	+
1	29	19	22	17	14	13	14	26	-5	38	+	+	+	+	+	+	+	+	+
0	32	27	32	25	22	18	7	13	-11	14	+	+	+	+	+	+	+	+	+

140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160

1° x 1° Mean Free-Air Anomalies (mgals)

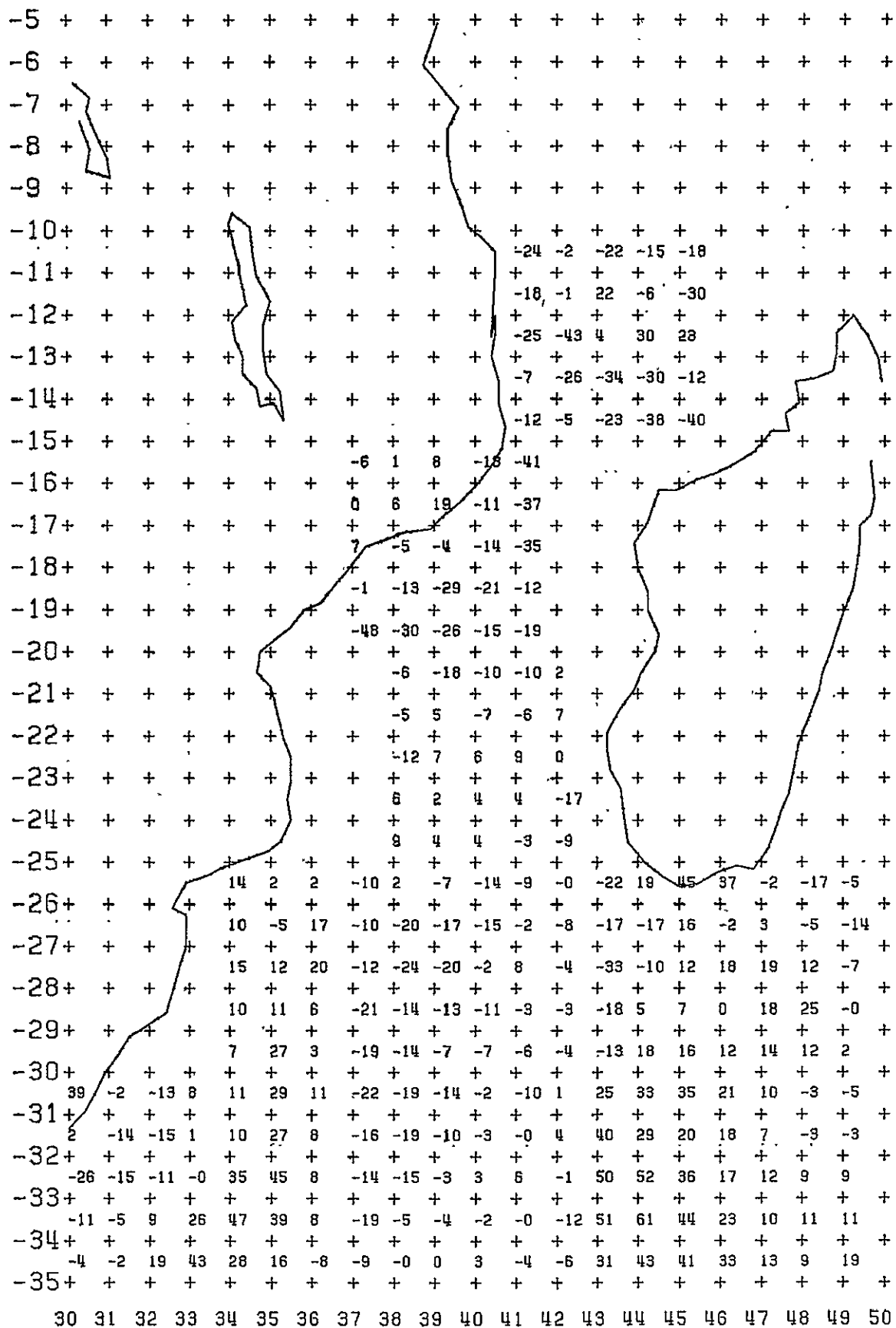
Figure B 4B

30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
29	8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
28	7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
27	12	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
26	9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
25	6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
24	6	7	11	7	13	7	8	6	8	13	+	+	+	+	+	+	+	+	+
23	7	6	7	10	7	8	6	6	7	9	+	+	+	+	+	+	+	+	+
22	7	8	6	9	6	10	6	10	6	7	+	+	+	+	+	+	+	+	+
21	7	8	7	6	10	6	10	8	7	6	+	+	+	+	+	+	+	+	+
20	6	9	7	6	8	6	12	10	6	6	+	+	+	+	+	+	+	+	+
19	8	7	6	8	6	12	8	6	7	7	6	+	+	+	+	+	+	+	+
18	7	5	7	7	6	10	9	6	9	6	7	+	+	+	+	+	+	+	+
17	8	6	6	6	10	7	6	6	6	7	9	+	+	+	+	+	+	+	+
16	7	6	5	6	13	6	7	8	6	13	6	+	+	+	+	+	+	+	+
15	6	8	6	7	9	7	6	6	8	8	7	+	+	+	+	+	+	+	+
14	7	6	7	8	6	8	7	8	13	+	+	+	+	+	+	+	+	+	+
13	7	6	10	7	6	8	7	7	7	+	+	+	+	+	+	+	+	+	+
12	7	7	8	6	7	6	9	9	7	+	+	+	+	+	+	+	+	+	+
11	7	13	7	7	7	7	7	7	6	+	+	+	+	+	+	+	+	+	+
10	7	12	7	7	6	6	7	9	6	+	+	+	+	+	+	+	+	+	+
9	7	7	8	7	7	7	6	+	+	+	+	+	+	+	+	+	+	+	+
8	6	6	10	7	7	8	6	+	+	+	+	+	+	+	+	+	+	+	+
7	7	6	6	7	7	6	6	+	+	+	+	+	+	+	+	+	+	+	+
6	6	7	6	10	9	6	7	+	+	+	+	+	+	+	+	+	+	+	+
5	6	6	6	7	7	6	7	+	+	+	+	+	+	+	+	+	+	+	+
4	7	6	7	6	7	7	6	10	7	6	+	+	+	+	+	+	+	+	+
3	6	6	7	6	6	7	7	7	7	6	+	+	+	+	+	+	+	+	+
2	6	6	6	6	6	7	12	7	7	7	+	+	+	+	+	+	+	+	+
1	6	7	5	6	6	7	13	6	6	7	+	+	+	+	+	+	+	+	+
0	9	6	5	5	6	7	7	7	6	6	+	+	+	+	+	+	+	+	+

140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160

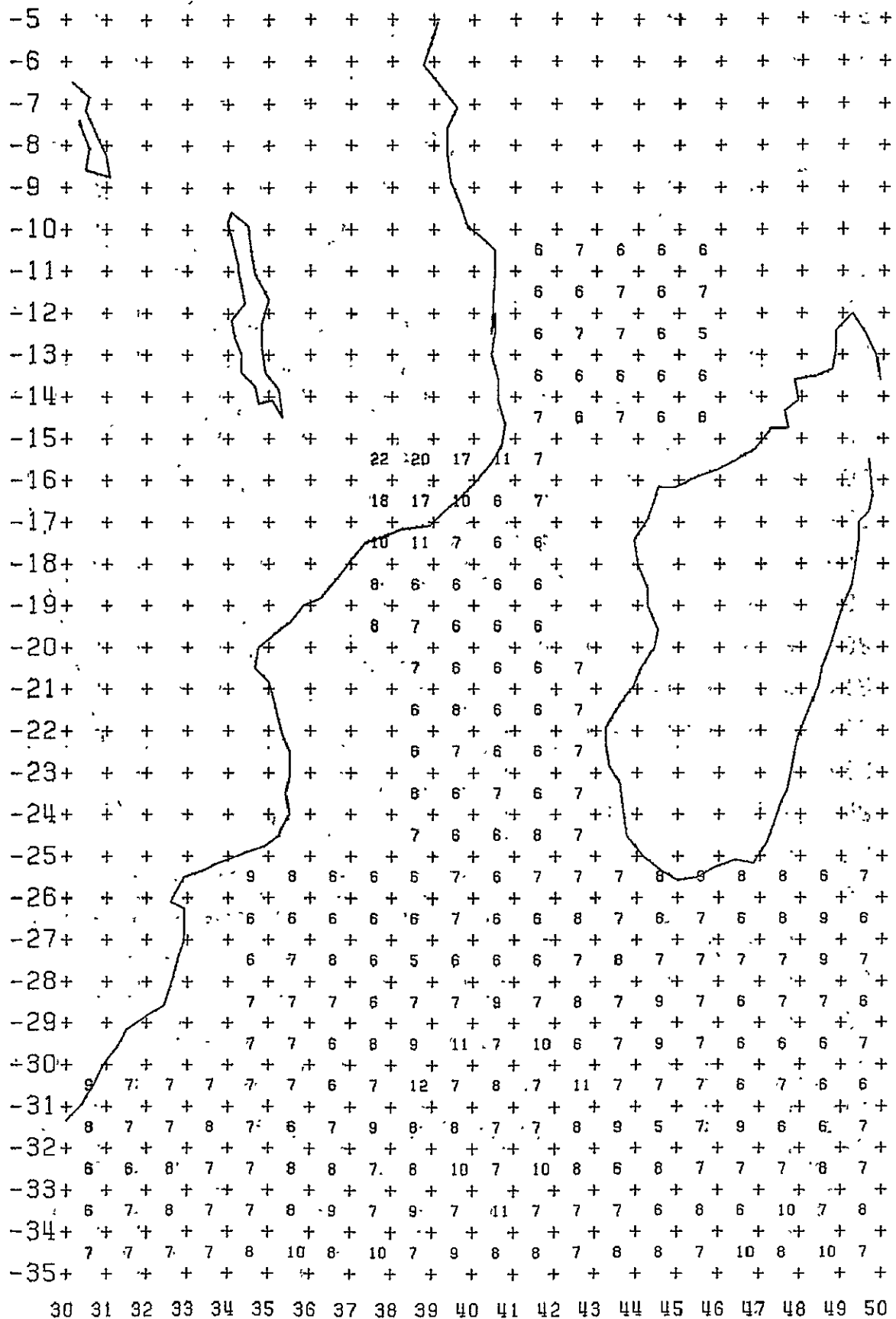
Accuracy of Predicted $1^\circ \times 1^\circ$ Mean Anomalies (mgals)

Figure B 5A



1°x 1° Mean Free-Air Anomalies (mgals)

Figure B 5 B



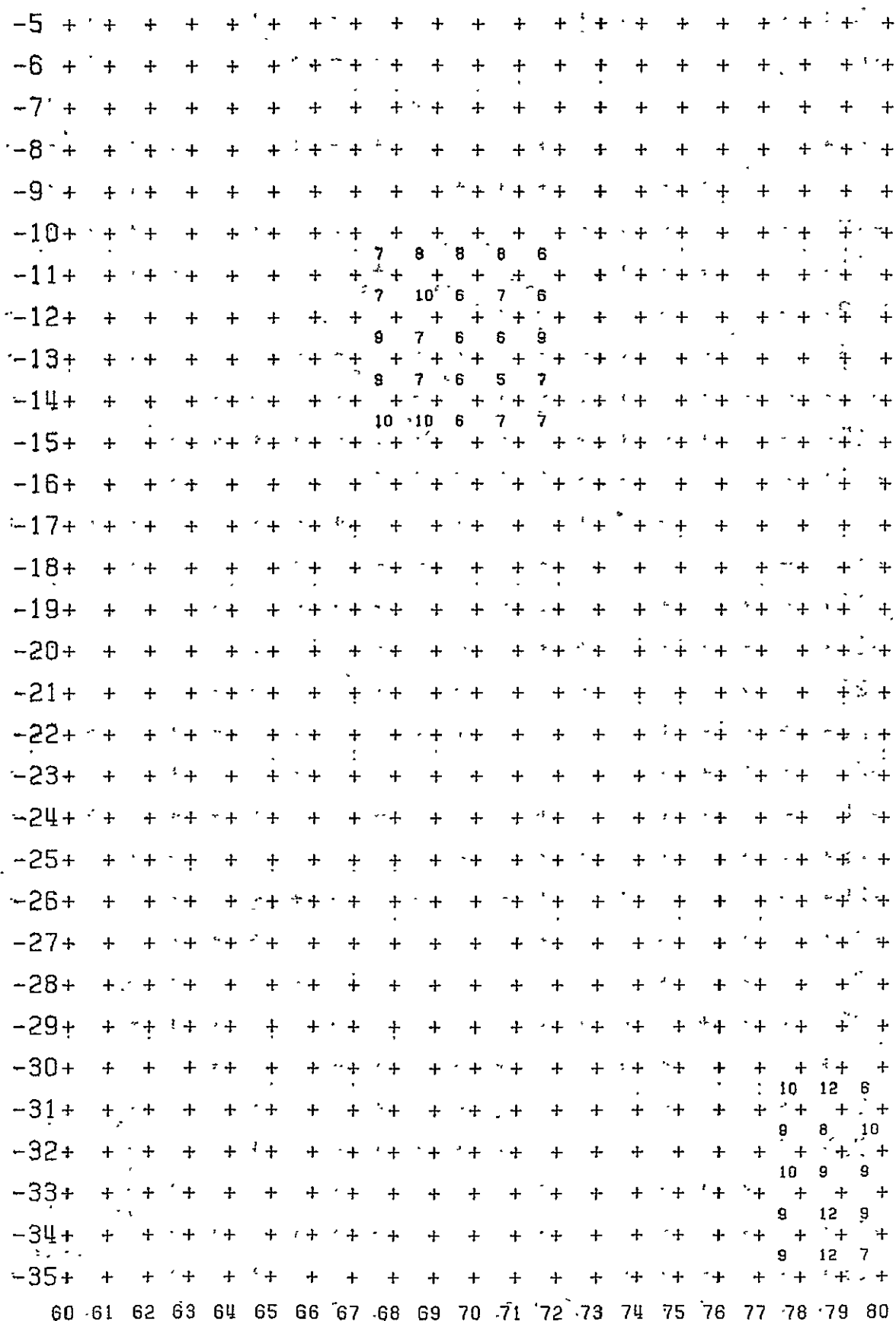
-Accuracy of Predicted 1°x1° Mean Anomalies (mgals)

Figure B 6A

-5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-11	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-12	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-13	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-14	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-15	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-16	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-17	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-18	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-19	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-21	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-22	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-23	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-26	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-27	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-28	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-29	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-31	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-32	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-33	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-34	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-35	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	80

1°x 1° Mean Free-Air Anomalies (mgals)

Figure B 6B



Accuracy of Predicted 1°x1° Mean Anomalies (mgals)

Figure B 7 A

ORIGINAL PAGE IS
OF POOR QUALITY

-5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-11	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-12	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-13	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-14	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-15	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-16	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-17	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-18	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-19	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-21	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-22	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-23	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-26	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-27	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-28	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-29	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-31	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-32	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-33	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-34	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-35	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

1°x 1° Mean Free-Air Anomalies.(mgals)

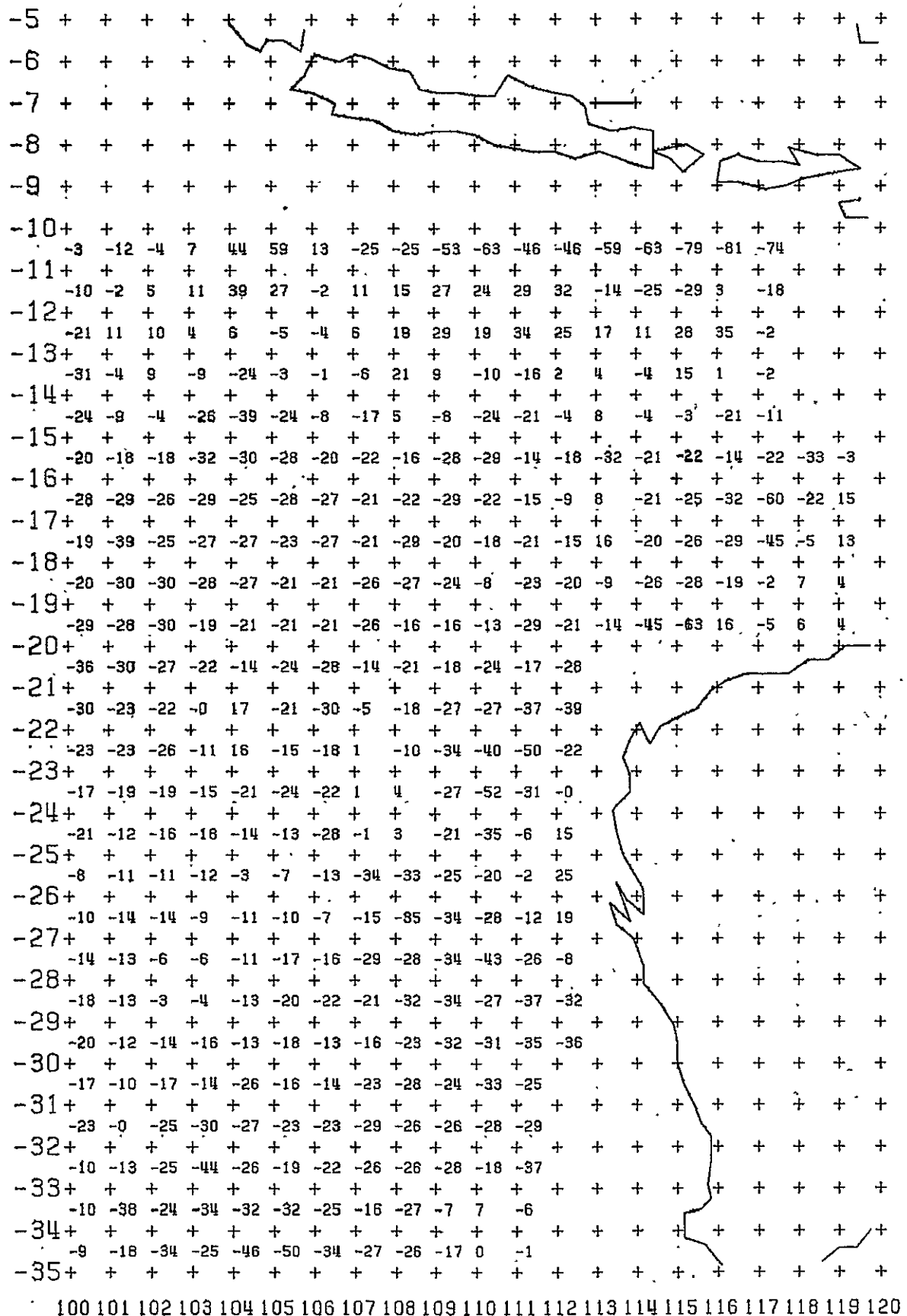
Figure B 7 B

-5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-11	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-12	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-13	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-14	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-15	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-16	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-17	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-18	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-19	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-21	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-22	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-23	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-26	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-27	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-28	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-29	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-31	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-32	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-33	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-34	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-35	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

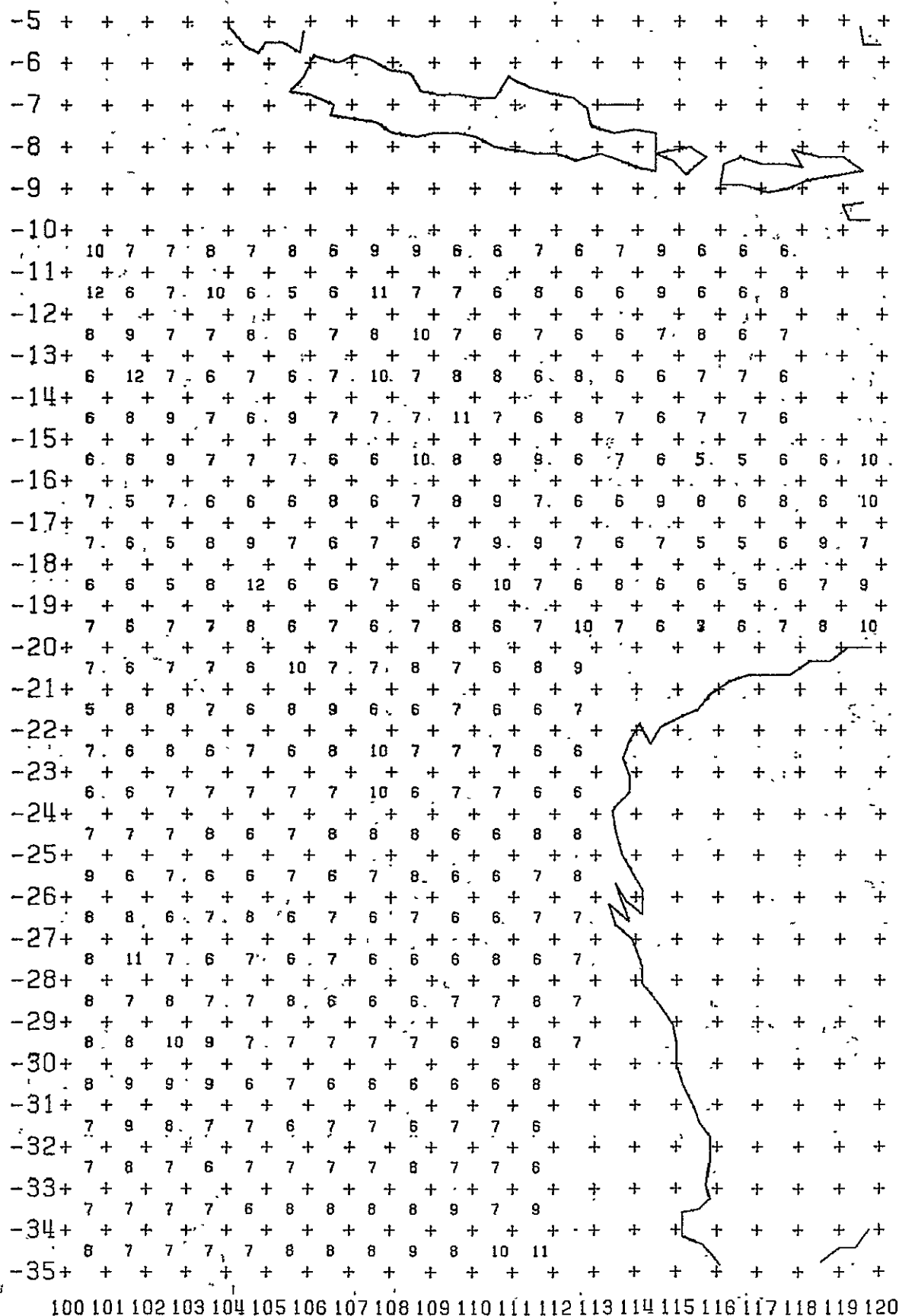
Accuracy of Predicted $1^{\circ} \times 1^{\circ}$ Mean Anomalies (mgals)

Figure B8A



1° x 1° Mean Free-Air Anomalies (mgals)

Figure B 8 B



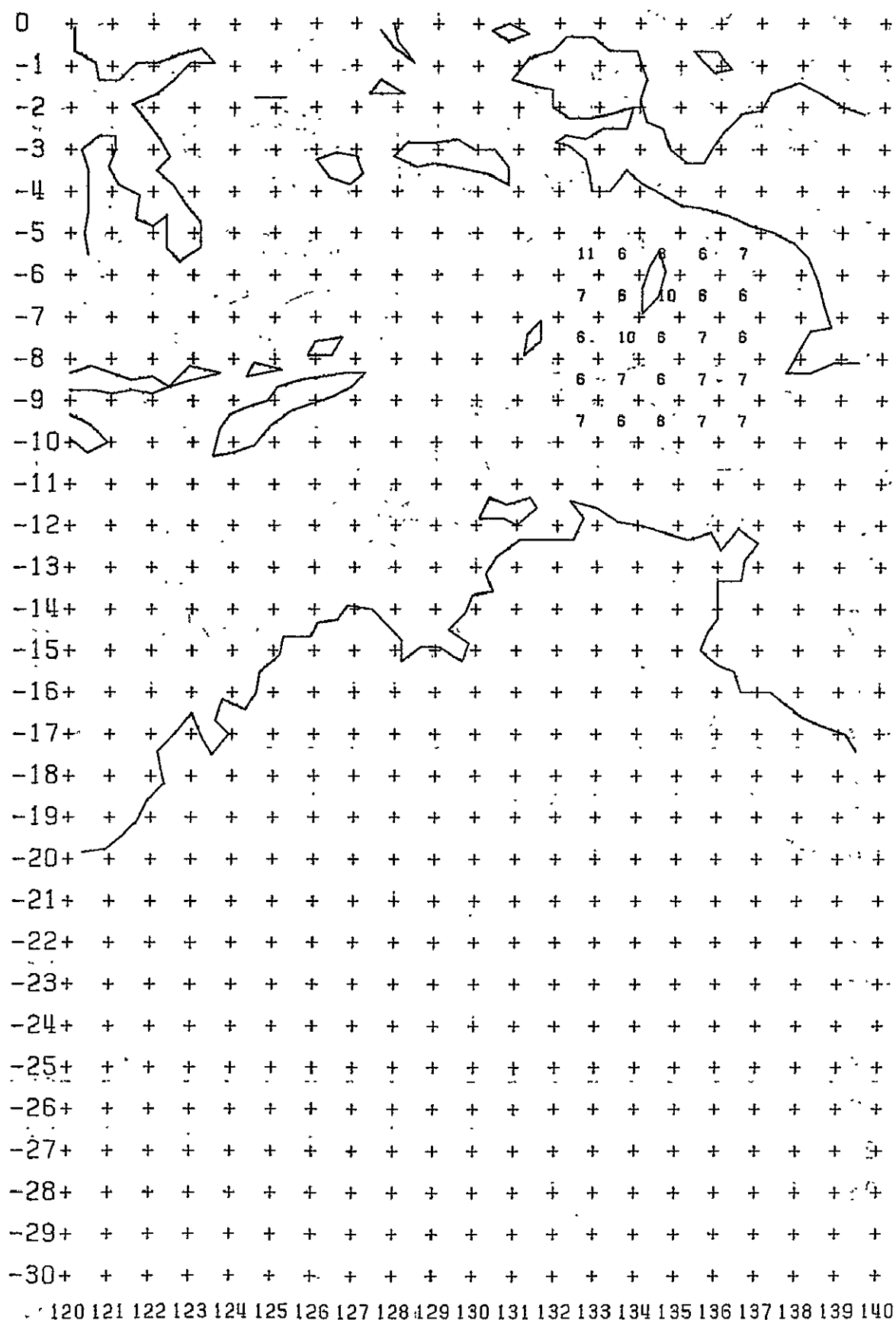
Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

A 31x31 grid of plus signs (+) with irregular black outlines. The grid is indexed from 0 to -30 on both the horizontal and vertical axes. A numerical data block is located in the upper right quadrant, spanning from column index -14 to -21 and row index -6 to -10. The data values are as follows:

Row \ Column	-14	-13	-12	-11	-10	-9	-8	-7	-6
-6	-14	-37	26	22	29				
-7	-63	-25	47	36	24				
-8	-5	50	60	36	25				
-9	30	41	27	40	23				
-10	38	40	24	42	21				

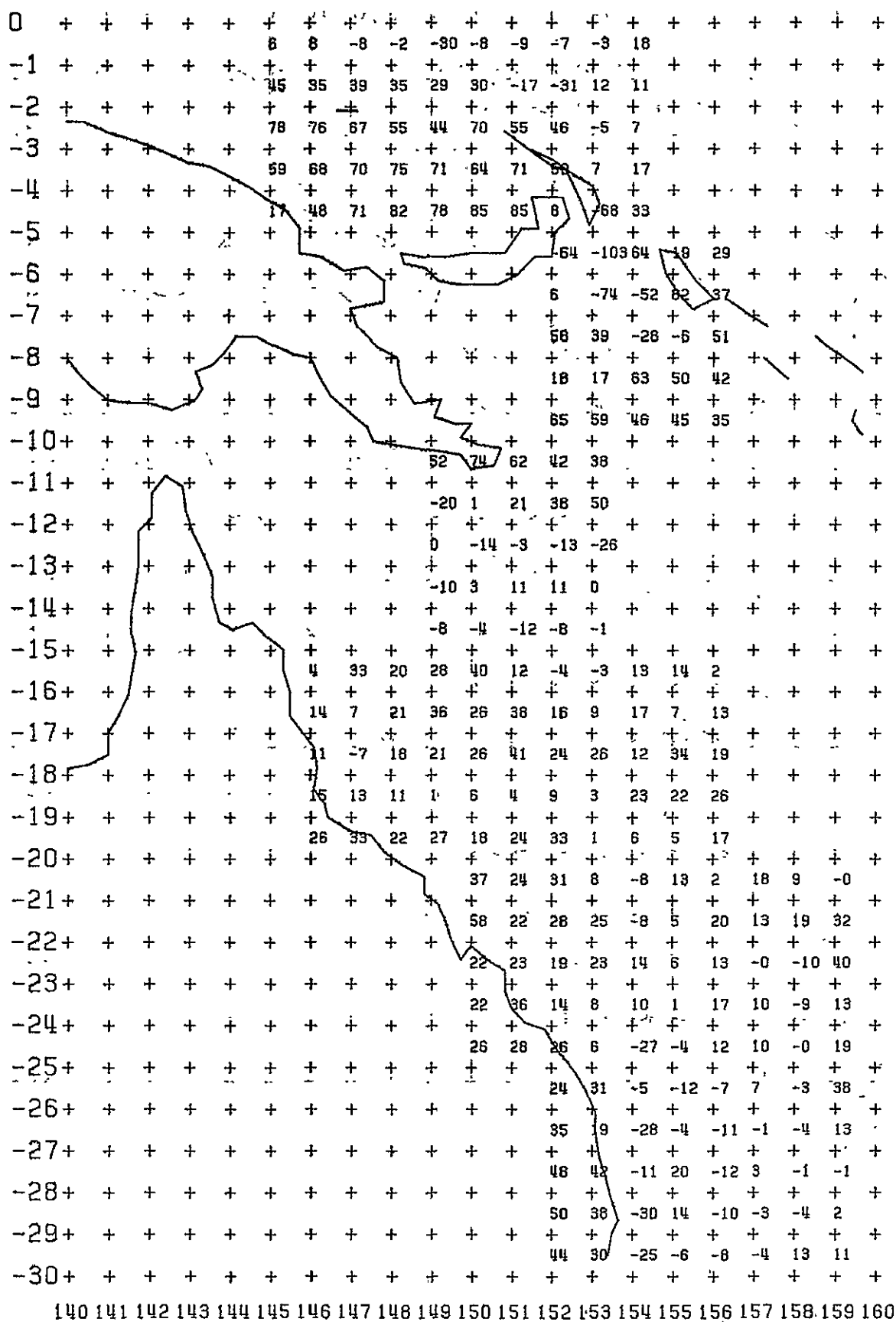
1° x 1° Mean Free-Air Anomalies (mgals)

Figure B.9B



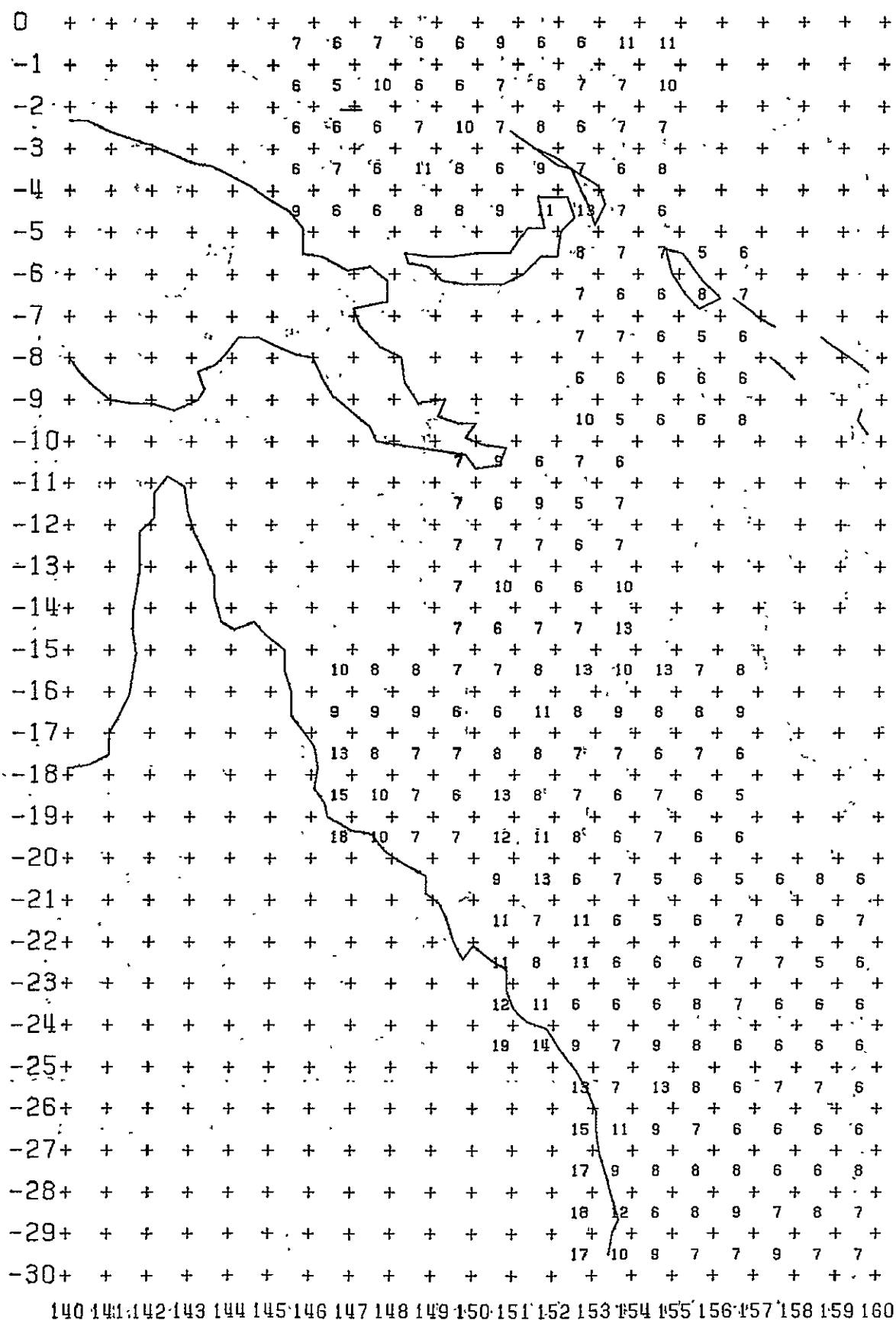
Accuracy of Predicted 1°x 1° Mean Anomalies (mgals)

Figure B10 A



1°x 1° Mean Free-Air Anomalies (mgals)

Figure B10 B



Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

Figure B11A

0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-4	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-11	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-12	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-13	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-14	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-15	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-16	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-17	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-18	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-19	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-21	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-22	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-23	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-26	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-27	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-28	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-29	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180

1°x 1° Mean Free-Air Anomalies (mgals)

ORIGINAL PAGE IS
OF POOR QUALITY

Figure B 11 B

0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-4	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-11	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-12	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-13	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-14	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-15	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-16	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-17	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-18	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-19	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-21	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-22	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-23	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-26	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-27	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-28	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-29	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180

Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

Figure B 12 A

0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-4	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-11	18	-22	-11	2	3	-4	1	14	13	-8	-13	2	10	-14	-4				
-12	25	18	19	0	-9	-13	-11	-3	20	8	-16	-4	-3	-12	9				
-13	-5	21	6	11	-1	29	-10	-12	-2	-3	-7	1	-12	4	-19				
-14	13	47	0	10	-5	2	-5	49	7	-2	21	-10	-14	4	-19				
-15	33	25	30	33	3	15	-28	-25	12	45	63	-6	-5	-10	-5				
-16	35	24	15	36	32	54	62	-89	-23	22	-6	-13	-4	-17	-5	-7	-13	3	
-17	32	15	21	25	33	60	80	-91	-27	42	-1	9	-16	-7	-2	-12	-14	8	
-18	15	18	24	21	44	74	92	-93	12	14	15	12	-14	-1	-2	-13	6	12	
-19	7	36	28	34	48	99	38	-95	16	19	36	9	-5	-6	-13	-5	-1	7	
-20	7	21	26	49	67	128	-39	-96	12	28	20	1	3	-1	-4	0	-2	-3	
-21	12	35	41	56	100	138	-102	-49	23	19	-6	6	-3	-6	2	9	6	2	6
-22	20	33	38	72	124	28	-105	5	25	9	11	1	-18	-12	-2	-4	-1	-3	8
-23	19	38	43	91	88	-136	-48	18	21	1	10	7	2	-0	-6	-8	-3	0	4
-24	29	41	50	100	-40	-118	9	25	11	6	-1	-2	-7	4	4	-6	-8	7	12
-25	27	48	52	93	-82	-45	37	23	11	3	6	-2	-4	-6	-1	2	-11	8	13
-26	30	49	79	75	-102	-5	46	30	21	2	-1	2	5	-10	-7	-7	-7	3	4
-27	40	51	83	23	-120	47	30	28	19	14	-2	6	9	-4	-6	2	-3	-13	-6
-28	47	61	87	9	-126	41	38	19	27	14	8	2	-8	-3	-8	7	6	-6	-9
-29	43	68	68	-59	-74	22	55	25	20	8	10	5	-0	-3	-3	5	2	1	-2
-30	58	101	28	-109	-22	20	27	12	11	17	3	8	6	5	13	6	2	-3	5

180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200

1° x 1° Mean, Free-Air Anomalies (mgals)

Figure B 12 B

0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-4	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-7	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-9	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-11	6	9	7	8	7	7	7	7	9	7	10	7	7	7	8				
-12	7	8	8	8	7	6	9	7	7	8	6	8	8	8	7				
-13	9	7	8	10	7	8	6	7	7	8	7	7	6	8	6				
-14	7	7	6	9	7	8	7	9	8	8	7	7	6	6	6				
-15	7	6	7	7	12	8	7	8	8	9	9	6	6	7	7				
-16	9	8	7	6	11	12	6	7	7	6	7	6	6	7	5	7	7	7	7
-17	7	7	6	8	7	8	11	6	7	8	5	6	6	6	6	6	7	7	7
-18	7	8	7	7	7	10	10	7	6	7	6	6	7	6	7	6	7	6	6
-19	6	6	9	8	7	7	7	8	7	6	7	7	6	6	6	7	6	7	7
-20	7	9	9	7	10	7	7	9	7	6	6	6	7	7	6	7	6	7	7
-21	7	6	9	9	7	7	5	9	7	6	6	6	6	7	7	6	6	7	10
-22	7	8	7	9	6	6	7	6	7	7	6	5	8	6	6	7	7	8	6
-23	9	7	6	9	7	6	7	6	6	7	6	6	7	6	6	7	7	8	6
-24	9	7	11	7	6	9	6	7	8	7	7	6	6	7	6	7	9	6	8
-25	6	9	8	8	9	7	6	7	7	7	8	7	6	7	7	8	7	6	8
-26	8	8	6	7	6	8	7	6	6	6	7	7	6	6	9	6	7	8	7
-27	10	6	10	7	6	6	9	6	6	5	7	7	7	7	6	8	8	8	6
-28	7	9	7	6	6	7	8	6	6	6	6	6	8	11	7	6	7	7	6
-29	10	7	7	6	7	7	7	7	7	6	8	7	10	9	7	6	10	6	6
-30	8	8	7	6	7	6	7	6	6	8	7	11	7	7	7	7	9	8	7

180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200

Accuracy of Predicted 1°x 1° Mean Anomalies (mgals)

Figure B13A

-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
					-10	-6	-6	-3	-7	-7	4	11	13	24	7	-12	-2	-0	-2
-36+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
					1	2	3	4	0	-3	7	17	11	17	-2	-11	-7	-1	7
-37+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
					18	15	11	7	4	0	11	7	14	14	3	-5	1	-1	7
-38+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
					18	13	4	9	18	6	9	6	15	12	-0	-1	2	3	15
-39+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
					25	23	14	15	20	-5	9	18	11	-1	2	-2	5	8	4
-40+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-5	-4	-2	1	16	37	24	26	16	6	-3	11	9	-2	12	-1	6	6	15
-41+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-0	-3	9	3	17	32	24	19	13	-5	-3	4	-7	-8	6	8	9	23	22
-42+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-4	7	14	17	15	18	12	5	-2	3	-5	-9	-12	1	8	11	18	29	25
-43+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	1	5	10	6	8	15	2	-8	6	-0	-10	-15	1	9	14	17	41	34	35
-44+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	7	4	7	6	10	3	-21	5	-0	-11	-10	-6	10	15	27	34	50	42	39
-45+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		10	3	6	2	3	-1	-17	-13	-4	5	11	19	41	46	39	34	26	24
-46+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		4	3	21	3	-6	-9	-14	-1	5	28	27	44	45	40	24	41	26	24
-47+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-8	-0	-1	-13	-6	3	1	14	18	11	27	39	39	28	14	15	-2	7	
-48+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		2	7	-1	-9	3	8	6	18	10	19	41	20	19	13	12	8	0	9
-49+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		6	6	7	5	6	6	15	10	12	16	21	9	2	11	20	6	-3	13
-50+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-51+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-52+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-53+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-54+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-55+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-56+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-57+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-58+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-59+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-60+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												9	17	9	7	8	11	11	
-61+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												-1	4	-0	1	8	13	20	
-62+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												-6	4	9	6	5	10	-4	
-63+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												-6	-3	0	4	6	7	9	
-64+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												-20	-3	-1	4	2	8	1	
-65+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
																			39
																			40

1°x 1° Mean Free-Air Anomalies (mgals)

Figure B 13 B

[illegible]

Accuracy of Predicted $1^{\circ} \times 1^{\circ}$ Mean Anomalies (mgals)

Figure B 14A

ORIGINAL PAGE IS
OF POOR QUALITY

-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-4	-3	-0	27	27	24	20	15	18	22	24									
-36+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1	1	7	28	30	31	16	20	30	32	37									
-37+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
14	8	11	23	21	23	24	37	35	47	50									
-38+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
24	24	19	30	22	22	31	55	47	44	36									
-39+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-2	34	27	34	39	34	49	40	30	25	16									
-40+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
9	32	28	36	37	42	23	22	16	17	18	18	23	12						
-41+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
26	29	19	22	32	23	11	16	20	20	25	16	21	16						
-42+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
32	26	20	17	20	17	17	17	22	27	23	20	32	25						
-43+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
44	23	13	14	19	14	13	12	21	21	17	14	19	27						
-44+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
32	24	15	21	20	16	26	28	12	4	7	7	12	25						
-45+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
27	28	25	8	17	39	42	19	-9	41	69	22	10	14	21	27	27	24	15	
-46+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
19	5	28	2	19	44	37	14	5	61	80	93	56	11	15	24	27	20	17	
-47+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11	4	-11	16	8	12	21	13	-4	2	6	13	8	12	20	24	22	16	20	
-48+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
12	16	13	4	6	7	15	12	15	15	14	12	17	21	17	18	23	19	18	
-49+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
20	15	8	4	1	7	17	22	19	12	14	16	24	23	17	14	14	10	9	
-50+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-51+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-52+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-53+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-54+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-55+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
9	11	14	12	6															
-56+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11	17	11	9	6															
-57+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	5	2	7	10															
-58+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
7	4	4	10	9															
-59+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
3	5	7	8	14															
-60+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
8	13	7	4	7	8	8	3	-1	-2	-4	-4	-4	2	6	2	2	4	9	12
-61+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
15	19	20	13	11	5	1	0	4	4	-0	-1	1	3	6	9	10	6	10	13
-62+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-20	19	18	12	10	-12	12	14	7	2	1	-4	3	0	2	10	14	14	12	11
-63+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
13	11	11	6	7	6	9	3	-10	-17	-13	-13	-11	-9	-3	-1	3	14	17	15
-64+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
11	17	15	4	1	-1	1	12	11	13	13	16	9	6	4	-3	4	7	9	7
-65+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

1°x 1° Mean Free-Air Anomalies (mgals)

Figure B14B

-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-36+	8	7	8	8	8	8	8	6	8	6	7	+	+	+	+	+	+	+	+
-37+	6	8	9	6	8	6	6	9	6	7	9	+	+	+	+	+	+	+	+
-38+	7	8	7	7	7	7	9	6	7	6	10	+	+	+	+	+	+	+	+
-39+	10	7	7	6	9	8	8	7	7	8	7	+	+	+	+	+	+	+	+
-40+	8	7	7	7	8	8	6	7	8	7	9	+	+	+	+	+	+	+	+
-41+	7	8	9	7	6	6	8	8	8	7	7	7	7	8	+	+	+	+	+
-42+	8	8	10	9	6	6	8	9	7	8	6	6	7	7	+	+	+	+	+
-43+	10	9	7	7	8	7	7	7	8	7	8	8	8	11	+	+	+	+	+
-44+	8	9	7	7	9	10	8	7	7	9	8	9	8	9	+	+	+	+	+
-45+	9	8	9	8	7	10	9	8	7	8	9	8	10	9	+	+	+	+	+
-46+	6	7	7	7	9	6	7	7	7	7	7	9	6	10	9	7	9	7	12
-47+	7	7	8	9	7	8	6	7	12	9	7	6	10	8	8	9	8	12	9
-48+	8	9	8	8	8	9	9	8	8	9	8	9	7	6	8	8	13	9	11
-49+	10	11	8	8	8	10	12	9	8	9	12	9	9	7	9	11	8	13	11
-50+	8	8	10	11	10	8	10	10	13	11	8	9	9	11	8	8	12	10	12
-51+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-52+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-53+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-54+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-55+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-56+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	9	8	10	15
-57+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	11	11	10	12
-58+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	10	11	9	10
-59+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	10	10	9	8
-60+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	10	9	8	7
-61+	8	9	9	10	12	14	13	13	12	11	11	13	10	10	11	10	9	8	10
-62+	8	9	9	11	10	9	11	12	12	9	10	9	11	10	11	9	10	11	8
-63+	7	9	9	8	8	8	8	7	10	8	10	10	10	10	8	9	9	9	10
-64+	9	9	9	9	10	9	8	9	7	9	7	9	8	8	8	9	9	9	11
-65+	8	8	8	8	8	9	9	9	8	10	8	10	9	9	9	9	8	8	9
-65+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58

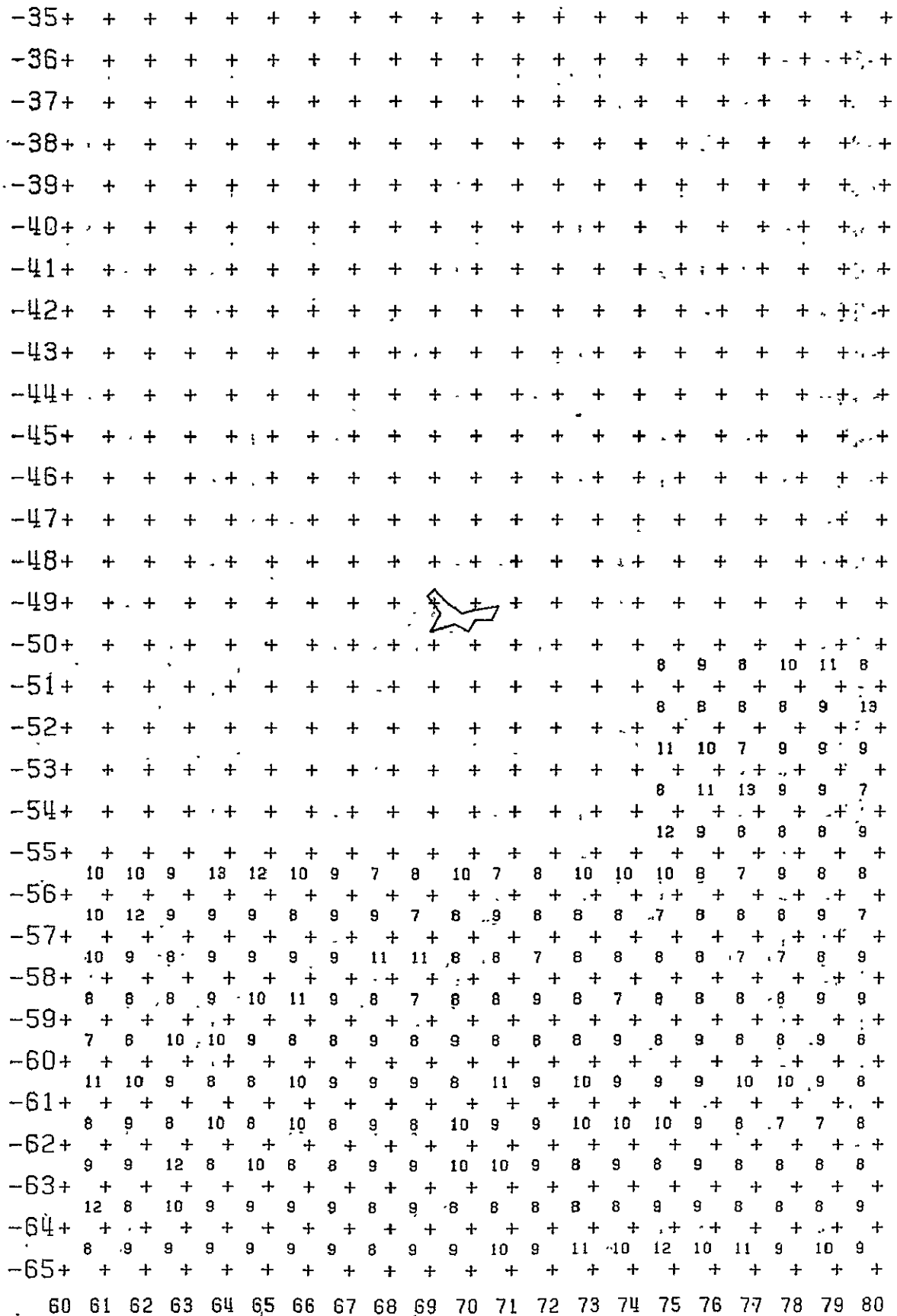
Accuracy of Predicted 1°x 1° Mean Anomalies (mgals)

Figure B 15 A

-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-36+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-37+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-38+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-39+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-40+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-41+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-42+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-43+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-44+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-45+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-46+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-47+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-48+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-49+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-50+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-51+	+	+	+	+	+	+	+	+	+	+	+	+	+	38	27	13	17	17	23
-52+	+	+	+	+	+	+	+	+	+	+	+	+	+	40	44	31	13	21	25
-53+	+	+	+	+	+	+	+	+	+	+	+	+	+	58	50	56	39	39	23
-54+	+	+	+	+	+	+	+	+	+	+	+	+	+	41	43	45	35	17	-7
-55+	+	+	+	+	+	+	+	+	+	+	+	+	+	31	35	33	24	20	2
-56+	4	6	6	6	15	14	8	0	2	11	26	22	17	19	14	13	33	32	19
-57+	7	8	5	9	25	43	40	40	49	20	24	41	33	18	19	21	22	14	24
-58+	8	12	14	15	8	-6	-6	2	10	10	5	19	20	13	15	18	19	13	29
-59+	10	10	8	5	-4	-6	8	16	11	8	4	-4	-2	16	27	38	49	34	36
-60+	12	10	7	0	-5	11	17	23	22	11	7	10	8	18	25	23	31	34	26
-61+	10	6	6	4	2	8	17	20	13	14	11	3	2	5	5	12	18	14	17
-62+	11	13	10	8	3	6	8	6	11	14	17	6	4	8	8	14	8	9	12
-63+	11	13	14	15	9	4	3	1	3	8	7	5	8	14	15	11	3	-1	-1
-64+	10	7	11	8	6	6	5	9	9	12	8	8	4	8	11	19	19	16	13
-65+	1	-1	9	10	8	-3	1	14	24	17	14	6	2	-4	2	7	7	10	10
60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79

1°x 1° Mean Free-Air Anomalies (mgals)

Figure B 15 B



Accuracy of Predicted 1°x 1° Mean Anomalies (mgals)

Figure B 16 A

-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-36+	+	+	+	+	+	+	+	-1	-2	3	2	-2	-3	-4	-9	-8	-15	-12	-9
-37+	+	+	+	+	+	+	+	-1	6	0	-5	-5	-4	-6	-12	-12	-10	-15	+
-38+	+	+	+	+	+	+	+	4	2	0	-0	1	-0	1	-7	-7	-5	-12	-16
-39+	+	+	+	+	+	+	+	8	2	5	-1	0	4	1	-6	-2	-3	-14	-6
-40+	+	+	+	+	+	+	+	10	10	5	6	9	1	3	5	1	-12	-4	-3
-41+	+	+	+	+	+	+	+	14	12	9	8	5	5	11	3	-6	1	-4	-3
-42+	+	+	+	+	+	+	+	14	11	15	9	10	11	7	-5	6	1	-1	-2
-43+	+	+	+	+	+	+	+	17	17	13	10	16	10	2	8	4	5	-1	-2
-44+	+	+	+	+	+	+	+	20	16	11	18	14	7	12	7	11	7	1	0
-45+	+	+	+	+	+	+	+	13	10	18	14	8	14	9	12	5	3	7	2
-46+	18	17	16	15	21	20	10	11	17	18	10	18	8	11	6	-0	9	2	5
-47+	20	16	17	23	24	14	15	21	5	12	18	12	15	5	6	12	6	10	8
-48+	15	16	25	24	16	15	24	14	22	15	13	14	12	8	14	10	14	13	8
-49+	22	22	14	21	21	16	15	19	20	14	13	14	14	13	13	15	12	10	12
-50+	24	18	20	20	12	17	20	16	15	15	11	13	15	14	17	11	9	8	3
-51+	26	24	26	22	16	21	14	11	10	15	16	15	18	10	13	10	9	12	6
-52+	31	23	15	18	23	24	16	11	14	18	16	14	14	14	11	13	3	7	9
-53+	20	13	23	23	14	10	14	16	16	13	10	10	13	8	11	15	10	8	11
-54+	21	21	16	13	12	15	13	11	12	13	7	12	12	9	12	11	10	13	9
-55+	-2	-10	1	-9	16	18	11	7	12	12	9	11	10	10	10	11	14	8	7
-56+	-4	-18	6	17	3	9	13	9	11	12	12	12	12	7	6	18	8	2	10
-57+	1	-16	-11	-3	-2	-0	14	11	10	16	19	14	10	10	8	10	15	-7	1
-58+	26	20	5	-10	-8	-6	4	16	12	16	7	5	16	21	15	10	13	8	4
-59+	29	36	36	13	-5	-8	4	7	7	5	10	13	12	9	11	13	7	3	-0
-60+	23	31	46	51	28	-17	-21	-9	1	5	4	1	6	9	4	10	7	4	-1
-61+	32	41	37	37	29	4	-1	3	-3	-4	1	3	-3	-11	-6	-3	2	1	-6
-62+	26	31	31	27	16	4	-4	-3	-6	-3	1	-6	-17	-20	-15	-9	-9	-7	-14
-63+	6	21	18	16	12	4	2	3	1	0	-2	-6	-13	-12	-13	-26	-22	-13	-20
-64+	-3	-4	6	14	11	4	1	2	1	-0	-2	-3	-7	1	5	-4	2	2	-1
-65+	1	2	6	13	14	9	12	12	6	-3	-11	-5	-2	11	24	34	43	37	29
-66+	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98

1° x 1° Mean Free-Air Anomalies (mgals)

Figure B 16 B

-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-36+	+	+	+	+	+	+	+	+	+	8	7	6	9	8	9	8	8	11	6
-37+	+	+	+	+	+	+	+	+	+	8	6	8	7	10	8	11	8	7	11
-38+	+	+	+	+	+	+	+	+	+	7	8	7	9	6	10	9	8	9	7
-39+	+	+	+	+	+	+	+	+	+	7	7	8	7	8	8	11	12	10	7
-40+	+	+	+	+	+	+	+	+	+	10	9	7	8	8	10	11	11	8	7
-41+	+	+	+	+	+	+	+	+	+	8	7	7	7	8	8	9	8	7	8
-42+	+	+	+	+	+	+	+	+	+	10	7	7	7	8	9	7	7	8	9
-43+	+	+	+	+	+	+	+	+	+	7	8	7	9	7	7	7	8	9	8
-44+	+	+	+	+	+	+	+	+	+	7	8	10	8	7	6	7	8	8	8
-45+	+	+	+	+	+	+	+	+	+	10	9	7	8	7	8	8	9	8	7
-46+	+	+	+	+	+	+	+	+	+	10	7	7	9	8	7	9	11	9	7
-47+	+	+	+	+	+	+	+	+	+	7	8	9	7	6	9	7	7	8	7
-48+	+	+	+	+	+	+	+	+	+	9	11	8	9	10	7	7	7	8	7
-49+	+	+	+	+	+	+	+	+	+	9	8	10	12	9	7	6	8	7	9
-50+	+	+	+	+	+	+	+	+	+	9	10	10	8	8	8	7	8	8	8
-51+	+	+	+	+	+	+	+	+	+	8	12	9	8	8	7	8	9	9	7
-52+	+	+	+	+	+	+	+	+	+	10	8	9	7	8	9	8	8	8	7
-53+	+	+	+	+	+	+	+	+	+	9	8	8	9	9	8	7	8	8	9
-54+	+	+	+	+	+	+	+	+	+	7	9	9	9	9	8	9	9	8	9
-55+	+	+	+	+	+	+	+	+	+	8	8	9	9	8	9	10	10	9	10
-56+	+	+	+	+	+	+	+	+	+	9	8	9	8	9	11	10	8	8	9
-57+	+	+	+	+	+	+	+	+	+	8	10	9	10	10	8	8	11	9	10
-58+	+	+	+	+	+	+	+	+	+	10	10	9	8	10	10	11	9	8	8
-59+	+	+	+	+	+	+	+	+	+	8	9	9	11	10	9	8	9	8	8
-60+	+	+	+	+	+	+	+	+	+	9	9	9	9	8	8	8	9	9	10
-61+	+	+	+	+	+	+	+	+	+	8	8	8	7	6	8	9	8	8	7
-62+	+	+	+	+	+	+	+	+	+	9	8	8	9	8	7	8	7	7	9
-63+	+	+	+	+	+	+	+	+	+	7	7	8	8	9	10	10	8	11	11
-64+	+	+	+	+	+	+	+	+	+	8	8	10	12	15	15	15	13	11	10
-65+	+	+	+	+	+	+	+	+	+	9	10	10	11	9	10	11	9	10	10
	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
	99	100																	

Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

1° x 1° Mean Free-Air Anomalies (mgals)

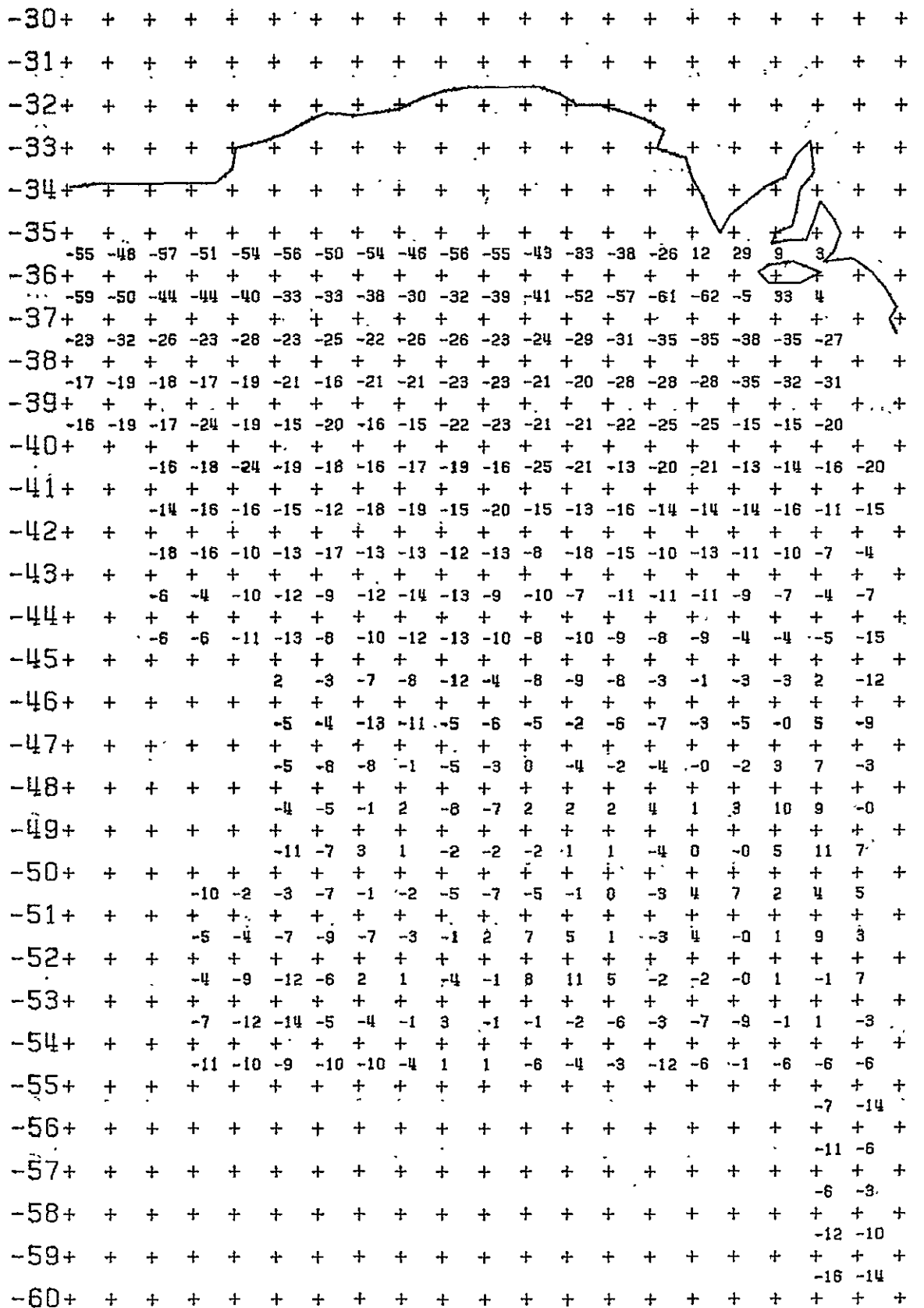
Figure B 17 B

-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-36+	7	7	6	6	7	7	8												
-37+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-38+	8	6	8	8	7	7	8												
-39+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-40+	8	8	8	7	9	8	8												
-41+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-42+	9	8	7	7	7	9	8	6	11										
-43+	7	7	8	7	8	9	7	8	8										
-44+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-45+	8	8	7	8	7	7	8	10	10										
-46+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-47+	10	10	8	8	7	7	9	8	14										
-48+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-49+	11	15	9	7	7	8	7	10	12										
-50+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-51+	9	10	8	9	8	7	11	7	8	8	7	9	8	8	11	8	9	11	
-52+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-53+	8	9	10	10	9	9	6	8	6	8	7	9	12	8	7	12	11	8	
-54+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-55+	8	10	9	10	12	8	7	8	7	7	8	9	9	9	10	8	10	13	
-56+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-57+	7	8	8	10	8	9	7	8	9	8	9	9	9	12	12	11	8	9	
-58+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-59+	8	8	8	8	7	8	10	10	10	9	9	8	8	9	10	12	10	10	
-60+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-61+	8	7	7	7	7	9	9	11	10	9	7	8	9	11	9				
-62+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-63+	9	8	9	7	8	9	8	7	8	8	10	9	8	8	12				
-64+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-65+	8	7	9	9	9	8	7	8	8	8	9	9	12	9	9				
-66+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-67+	9	8	9	9	8	8	8	7	7	9	11	12	10	13	16				
-68+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-69+	10	11	9	8	9	9	8	9	10	9	9	10	10	10	15				
-70+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-71+	7	8	9	10	8	8	7	10	9	10	10	8	8	9	10	13	13	11	12
-72+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-73+	7	7	9	9	9	9	9	10	9	10	11	8	8	7	7	8	10	11	12
-74+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-75+	9	9	8	9	8	11	13	11	12	10	9	9	8	7	8	9	8	10	13
-76+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-77+	9	11	10	13	10	11	11	12	12	10	9	8	7	7	8	13	14	11	14
-78+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-79+	11	12	12	11	11	12	12	9	9	8	9	9	8	8	9	11	13	16	15
-80+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-81+	12	10	9	8	7	7	7	7	7										
-82+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-83+	7	6	7	7	6	7	8	7	7										
-84+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-85+	7	7	7	8	8	8	11	13											
-86+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-87+	10	12	14	15	15	15	14	11	11										
-88+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-89+	17	17	17	15	12	13	14	14	15										
-90+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120

Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

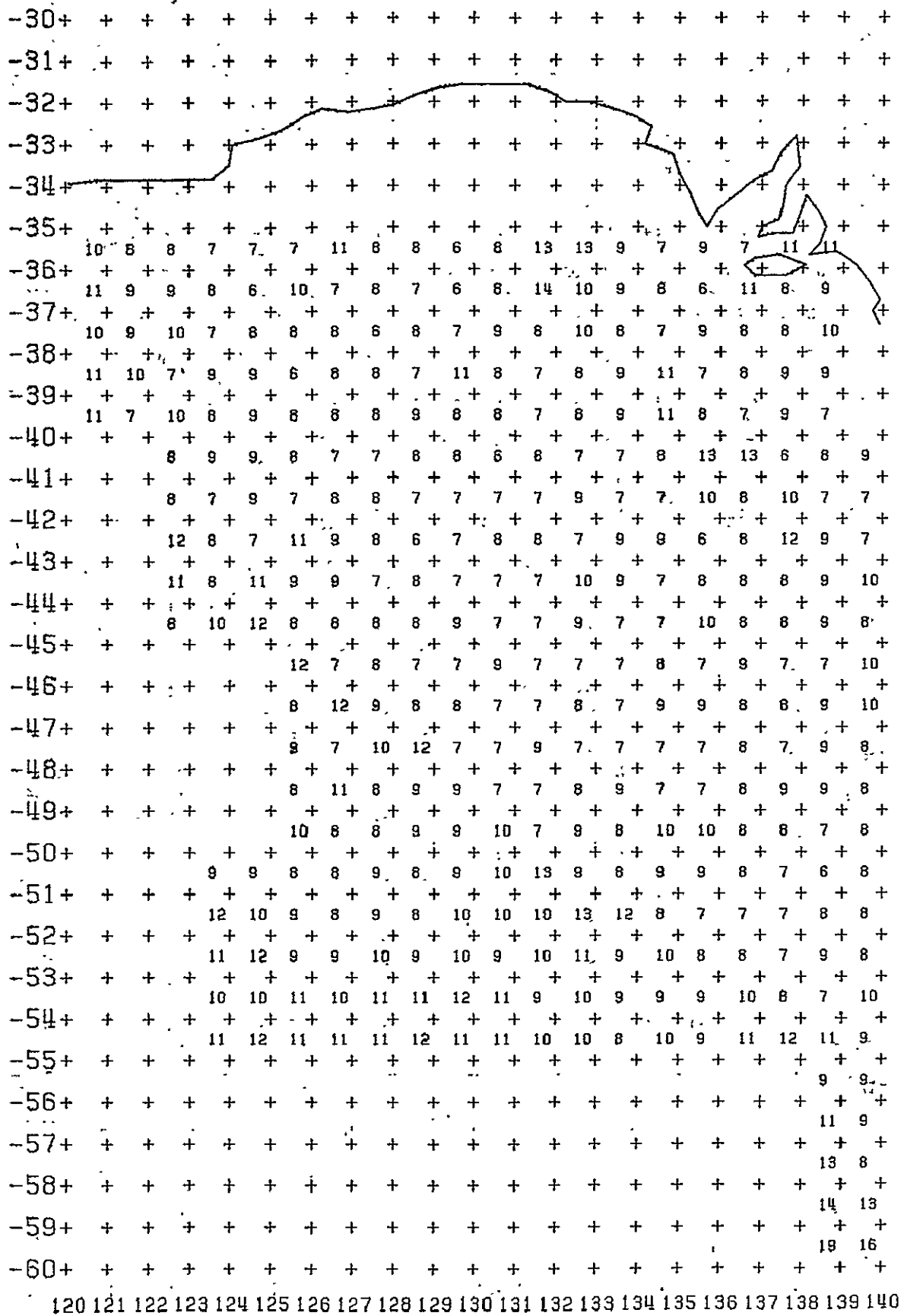
Figure B 18 A



120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140

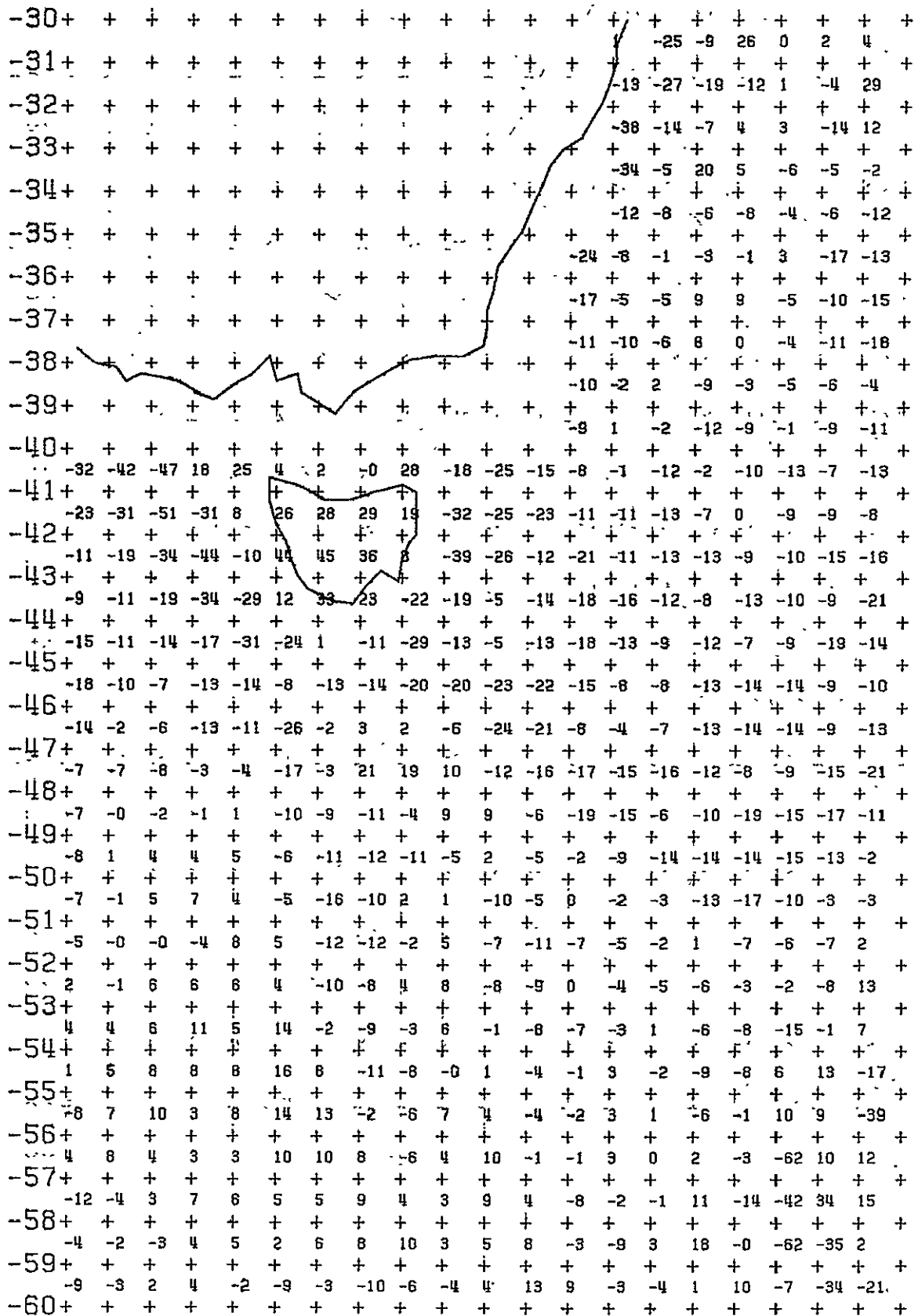
1° x 1° Mean Free-Air Anomalies (mgals)

Figure B 18 B



Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

Figure B 19 A



140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160

1°x 1° Mean Free-Air Anomalies (mgals)

-30+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-31+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-32+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-33+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-34+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-36+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-37+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-38+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-39+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-40+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-41+	8	8	6	6	7	12	7	7	9	8	7	6	9	8	6	8	8	9	7
-42+	9	7	7	7	9	14	16	15	7	7	7	8	7	7	7	8	7	7	8
-43+	7	7	8	11	7	10	16	13	7	8	9	9	7	7	9	8	7	10	8
-44+	6	8	9	11	9	10	7	8	8	7	9	8	9	8	7	7	9	8	8
-45+	13	8	8	7	9	8	7	8	8	8	7	7	8	9	7	8	10	8	9
-46+	13	10	7	7	7	7	8	8	8	7	7	9	8	7	8	9	7	10	8
-47+	9	8	8	7	7	7	9	10	7	7	9	7	6	7	9	9	9	8	9
-48+	8	8	7	7	9	8	8	8	9	11	8	7	9	8	8	10	9	8	7
-49+	8	6	7	9	8	8	7	9	11	9	8	9	9	8	9	7	8	9	8
-50+	7	9	9	9	8	8	11	9	8	8	11	10	9	10	8	8	8	9	9
-51+	8	7	8	6	8	9	9	8	10	8	7	10	9	8	8	8	7	9	8
-52+	8	8	7	8	9	7	8	9	9	11	9	8	8	9	9	9	9	7	8
-53+	8	8	9	8	7	8	9	9	8	9	9	8	8	9	10	11	8	8	7
-54+	10	9	7	8	10	9	8	9	8	8	8	10	12	10	9	8	9	9	8
-55+	8	9	10	9	10	11	8	9	8	9	10	9	8	9	10	9	8	8	11
-56+	9	8	8	8	6	7	8	9	10	9	8	8	8	8	7	8	9	8	7
-57+	9	8	8	8	8	9	9	10	10	8	8	9	7	7	8	9	7	7	9
-58+	9	8	9	10	10	9	9	9	10	10	8	8	8	8	7	7	8	11	9
-59+	10	11	10	12	11	11	10	8	9	10	11	9	9	8	10	10	9	8	10
-60+	12	11	9	11	12	10	10	11	9	9	10	10	11	10	9	10	11	10	9

Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

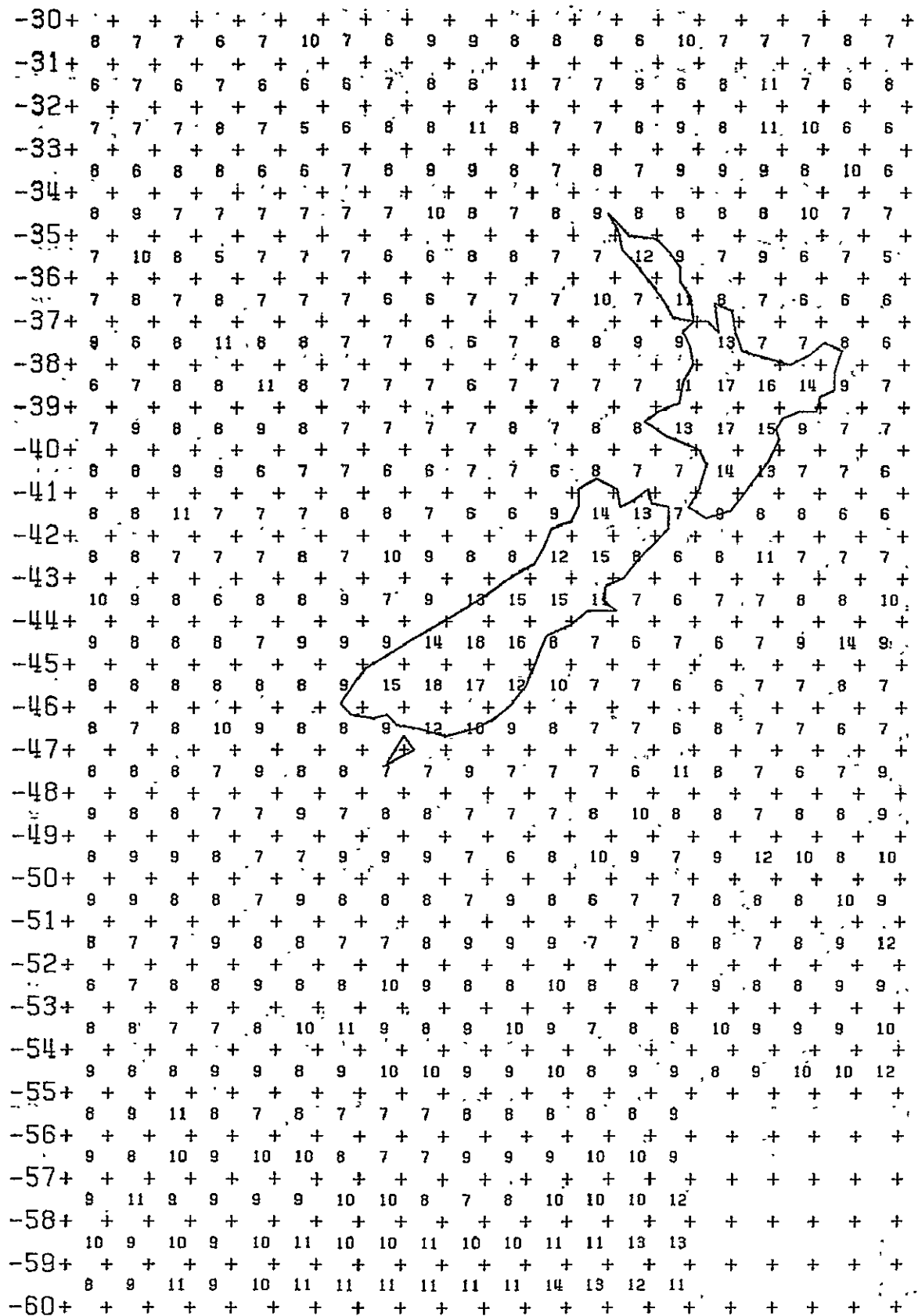
Figure B 20 A

-30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	10	13	13	7	-10	2	1	17	15	18	18	22	36	28	16	22	17	27	27	56
-31	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	14	14	8	7	-15	-15	19	14	19	8	20	30	26	20	18	9	12	27	33	56
-32	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	15	8	14	4	3	-1	18	31	8	6	9	21	22	20	19	24	21	28	48	66
-33	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	17	10	14	20	3	9	-6	30	6	22	20	17	21	20	6	27	35	33	57	88
-34	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	11	5	13	17	9	-9	-5	5	15	27	12	28	47	38	31	27	34	44	67	83
-35	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-7	-5	8	6	25	21	-7	-2	8	24	15	6	23	43	55	48	36	57	60	37
-36	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-5	-2	4	-1	9	26	5	14	3	14	19	6	8	21	39	51	45	20	-13	-14
-37	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-16	-7	-16	-1	17	0	14	26	25	13	13	11	20	28	41	49	52	10	50	-43
-38	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-5	-12	-8	-9	7	7	-4	30	28	39	5	16	18	29	45	29	18	4	-1	-1
-39	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-14	-16	-10	2	13	13	-6	18	38	18	11	1	22	10	-19	-20	-7	-14	19	18
-40	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-6	-1	-9	-1	4	-19	-6	21	15	23	12	5	34	1	-69	-28	15	17	-5	18
-41	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-11	-8	2	-3	-5	-2	-6	20	8	7	18	19	27	-2	-31	16	-12	-12	17	42
-42	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-13	-8	-4	-3	-10	-3	5	0	7	-7	19	39	22	-7	-54	-18	-9	9	37	25
-43	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-15	-6	-9	-11	-6	-6	-5	-13	-9	9	28	29	20	27	39	62	56	58	42	44
-44	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-10	-15	-1	-2	-1	-15	-48	-40	-12	10	28	2	18	13	26	35	23	0	4	9
-45	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-7	-7	-7	4	-8	-47	-31	8	27	46	37	0	-15	-7	-2	-2	-1	13	-9	-14
-46	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-13	-2	9	1	-15	-2	43	53	53	34	7	-18	-8	-7	-7	-5	-5	-4	-12	-13
-47	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-10	3	12	2	-45	-28	14	38	14	-7	-18	-10	-1	-4	1	6	0	6	20	35
-48	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-4	3	13	-15	-39	-6	29	28	2	-9	-6	3	-1	5	24	8	3	10	16	36
-49	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	2	5	-6	7	27	-7	14	7	-3	0	-1	8	23	16	12	10	6	12	16	3
-50	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-4	7	30	52	-13	-2	38	17	8	11	9	12	7	9	6	-5	-19	-20	-22	-23
-51	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	24	22	12	-5	-29	-0	19	11	12	9	3	6	2	11	13	-11	-34	-31	-18	-20
-52	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	38	-13	-2	-14	-30	6	10	-1	14	28	9	16	16	7	-17	-27	-26	-18	-17	-19
-53	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	7	9	-3	-14	-10	11	5	3	1	7	11	15	19	4	-19	-30	-30	-18	-16	-16
-54	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-24	-22	-13	-16	8	13	11	19	16	8	-3	-23	-45	-45	-29	-15	-19	-22	-21	-23
-55	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-23	-12	-27	-38	-41	-7	18	-1	-20	-34	-40	-41	-35	-37	-37					
-56	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-1	-4	-21	-36	-53	-32	-21	-26	-33	-31	-32	-33	-27	-27	-32					
-57	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-17	-13	-15	-28	-33	-29	-28	-29	-32	-31	-20	-23	-33	-32	-32					
-58	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-16	-22	-34	-29	-19	-21	-18	-22	-30	-42	-44	-39	-38	-35	-33					
-59	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-21	-20	-19	-10	-15	-29	-20	-27	-35	-35	-37	-39	-38	-35	-33					
-60	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180

1°x 1° Mean Free-Air Anomalies (mgals)

Figure B 20 B



Accuracy of Predicted 1°x 1° Mean Anomalies (mgals)

Figure B 21 A

-30+	78	95	-60	-113	29	31	35	15	-0	10	-3	4	0	2	5	4	2	5	4	1	+	+
-31+	96	58	-141	-53	39	44	8	25	-0	-8	4	3	-0	6	-6	-0	7	-0	7	9	+	+
-32+	122	-16	-154	-1	44	87	12	-1	28	-5	5	5	7	-0	-9	-2	13	5	6	9	+	+
-33+	81	-112	-83	28	43	23	24	-0	20	1	-1	7	6	-4	-5	4	7	1	1	11	+	+
-34+	-21	-124	-20	40	28	28	24	4	5	-0	-1	9	12	-1	10	8	3	3	-1	6	+	+
-35+	-69	-87	17	21	28	23	5	6	4	32	13	6	8	1	6	8	-1	4	0	-2	+	+
-36+	-74	-27	24	28	23	11	6	7	2	2	8	2	9	16	13	0	6	3	8	7	+	+
-37+	-5	32	29	31	18	6	3	-3	7	4	21	5	7	10	9	7	6	-0	5	18	+	+
-38+	34	27	40	19	13	1	-5	-2	14	2	-16	29	33	-4	6	15	5	3	11	15	+	+
-39+	27	30	19	9	12	-9	-8	-5	3	-19	-6	-6	16	22	2	-1	13	10	7	11	+	+
-40+	55	29	14	11	-1	-4	2	-11	-13	1	-2	5	-7	3	17	-3	-0				+	+
-41+	29	19	17	19	16	14	5	-3	1	3	-3	1	6	-5	-7	38	21				+	+
-42+	17	18	15	8	17	11	10	15	10	4	3	2	-7	0	0	5	13				+	+
-43+	41	29	39	53	39	24	17	6	3	1	-3	-6	-12	-4	2	-0	3				+	+
-44+	18	28	32	41	32	14	-3	-2	-6	-10	-11	-11	-8	-3	-11	-10	3				+	+
-45+	-9	-13	-8	-7	-2	-2	-3	-7	-14	-15	-11	-7	-11	-12	-7	-8	-10	-5	-7	-1	+	+
-46+	-19	-34	-22	-6	-12	-11	-4	-7	-12	-8	-4	-7	-8	-11	-3	1	-1	-6	-3	-2	+	+
-47+	18	-22	-17	-16	-15	-23	-13	-7	-6	-3	-6	-5	-4	-10	-9	-6	4	4	1	-3	+	+
-48+	37	-12	-19	-15	-15	-11	-17	-22	-6	-1	-8	-4	-3	-3	-1	-4	4	1	-1	-3	+	+
-49+	-1	-6	-0	5	-20	-24	-15	-9	-14	-5	2	-7	-12	-3	0	-1	-3	-4	1	-5	+	+
-50+									-0	-6	-14	-8	-7	-9	-9	-5	-4	-4	-5	-1	+	+
-51+									-8	-2	-2	-10	-9	-9	-13	-11	-6	-7	-8	-1	+	+
-52+									-11	-7	-9	-11	-8	-11	-9	-5	-5	-10	-12	-10	+	+
-53+									-20	-14	-11	-15	-14	-13	-14	-9	-6	-10	-13	-11	+	+
-54+									-16	-17	-12	-14	-15	-12	-8	-15	-19	-6	-6	0	+	+
-55+																-7	-9	-16	-13	-17	+	+
-56+																-15	-14	-12	-2	-4	+	+
-57+																-23	-15	-11	-11	-9	+	+
-58+																-15	-13	-9	-6	-9	+	+
-59+																-15	-12	-7	-6	-6	+	+
-60+																					+	+

180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200

1°x 1° Mean Free-Air Anomalies (mgals)

C-2

Figure B 21 B

-30+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-31+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-32+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-33+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-34+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-36+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-37+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-38+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-39+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-40+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-41+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-42+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-43+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-44+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-45+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-46+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-47+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-48+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-49+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-50+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-51+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-52+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-53+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-54+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-55+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-56+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-57+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-58+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-59+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-60+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200

Accuracy of Predicted 1°x 1° Mean Anomalies (mgals)

Figure B-22 A

-20+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-21+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-22+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-23+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-24+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-25+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-26+	+	+	-3	-1	2	19	5	+	+	+	+	+	+	+	+	+	+	+	+
-27+	+	+	-5	-8	-6	4	-3	+	+	+	+	+	+	+	+	+	+	+	+
-28+	+	+	-11	-10	-2	-4	-1	+	+	+	+	+	+	+	+	+	+	+	+
-29+	+	+	-10	1	-4	3	-9	+	+	+	+	+	+	+	+	+	+	+	+
-30+	+	+	-1	5	-3	-2	-22	+	+	+	+	+	+	+	+	+	+	+	+
-31+	-13	-3	-5	-5	1	0	1	+	+	+	+	+	+	+	+	+	+	+	+
-32+	9	-6	3	-2	-0	-1	14	+	+	+	+	+	+	+	+	+	+	+	+
-33+	10	2	-3	5	-3	10	13	+	+	+	+	+	+	+	+	+	+	+	+
-34+	5	6	-2	1	10	4	-1	+	+	+	+	+	+	+	+	+	+	+	+
-35+	10	5	5	-2	9	4	4	+	+	+	+	+	+	+	+	+	+	+	+
-36+	8	3	2	7	-7	-2	2	5	+	+	+	+	+	+	+	+	+	+	+
-37+	5	7	6	-2	-6	4	0	1	+	+	+	+	+	+	+	+	+	+	+
-38+	15	10	14	4	5	-1	-3	1	+	+	+	+	+	+	+	+	+	+	+
-39+	20	14	10	11	8	6	4	1	+	+	+	+	+	+	+	+	+	+	+
-40+	18	18	5	13	16	19	14	9	+	+	+	+	+	+	+	+	+	+	+
-41+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-42+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-43+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-44+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-45+	10	13	33	13	5	19	+	+	+	+	+	+	+	+	+	+	+	+	+
-46+	-2	-4	-1	10	11	16	+	+	+	+	+	+	+	+	+	+	+	+	+
-47+	-3	-2	2	6	7	2	+	+	+	+	+	+	+	+	+	+	+	+	+
-48+	-9	-9	-4	4	4	8	+	+	+	+	+	+	+	+	+	+	+	+	+
-49+	-2	-0	-6	-7	-6	0	+	+	+	+	+	+	+	+	+	+	+	+	+
-50+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220

1°x 1° Mean Free-Air Anomalies (mgals)

Figure B 22 B

-20+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-21+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-22+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-23+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-24+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-25+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-26+	+	+	+	9	10	6	7	7	+	+	+	+	+	+	+	+	+	+	+	
-27+	+	+	+	10	6	6	8	8	+	+	+	+	+	+	+	+	+	+	+	
-28+	+	+	+	8	7	7	7	12	+	+	+	+	+	+	+	+	+	+	+	
-29+	+	+	+	7	6	7	10	8	+	+	+	+	+	+	+	+	+	+	+	
-30+	+	+	+	7	7	9	7	9	+	+	+	+	+	+	+	+	+	+	+	
-31+	8	7	6	6	8	8	10	+	+	+	+	+	+	+	+	+	+	+	+	
-32+	6	6	6	7	7	7	8	+	+	+	+	+	+	+	+	+	+	+	+	
-33+	7	6	7	7	8	7	7	+	+	+	+	+	+	+	+	+	+	+	+	
-34+	7	7	7	8	10	8	8	+	+	+	+	+	+	+	+	+	+	+	+	
-35+	7	8	8	9	10	8	8	+	+	+	+	+	+	+	+	+	+	+	+	
-36+	6	9	10	8	7	10	10	10	+	+	+	+	+	+	+	+	+	+	+	
-37+	9	7	9	7	8	7	10	13	+	+	+	+	+	+	+	+	+	+	+	
-38+	9	10	7	9	8	8	10	11	+	+	+	+	+	+	+	+	+	+	+	
-39+	11	8	8	11	10	11	8	13	+	+	+	+	+	+	+	+	+	+	+	
-40+	7	9	13	9	10	9	15	11	+	+	+	+	+	+	+	+	+	+	+	
-41+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-42+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-43+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-44+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-45+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	
-46+	8	8	9	10	8	11	+	+	+	+	+	+	+	+	+	+	+	+	+	
-47+	11	9	8	10	10	8	+	+	+	+	+	+	+	+	+	+	+	+	+	
-48+	9	12	10	9	9	10	+	+	+	+	+	+	+	+	+	+	+	+	+	
-49+	10	9	12	9	10	8	+	+	+	+	+	+	+	+	+	+	+	+	+	
-50+	11	9	8	10	12	11	+	+	+	+	+	+	+	+	+	+	+	+	+	
200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220

Accuracy of Predicted 1°x1° Mean Anomalies (mgals)

ORIGINAL PAGE IS
OF POOR QUALITY

Figure B.23 A

-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-36+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-37+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-38+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-39+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-40+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-41+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-42+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-43+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-44+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-45+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-46+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-47+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-48+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-49+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-50+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-51+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-52+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-53+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-54+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-55+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-56+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-57+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-58+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-59+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-60+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-61+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-62+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-63+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-64+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-65+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280

1°x1° Mean Free-Air Anomalies (mgals)

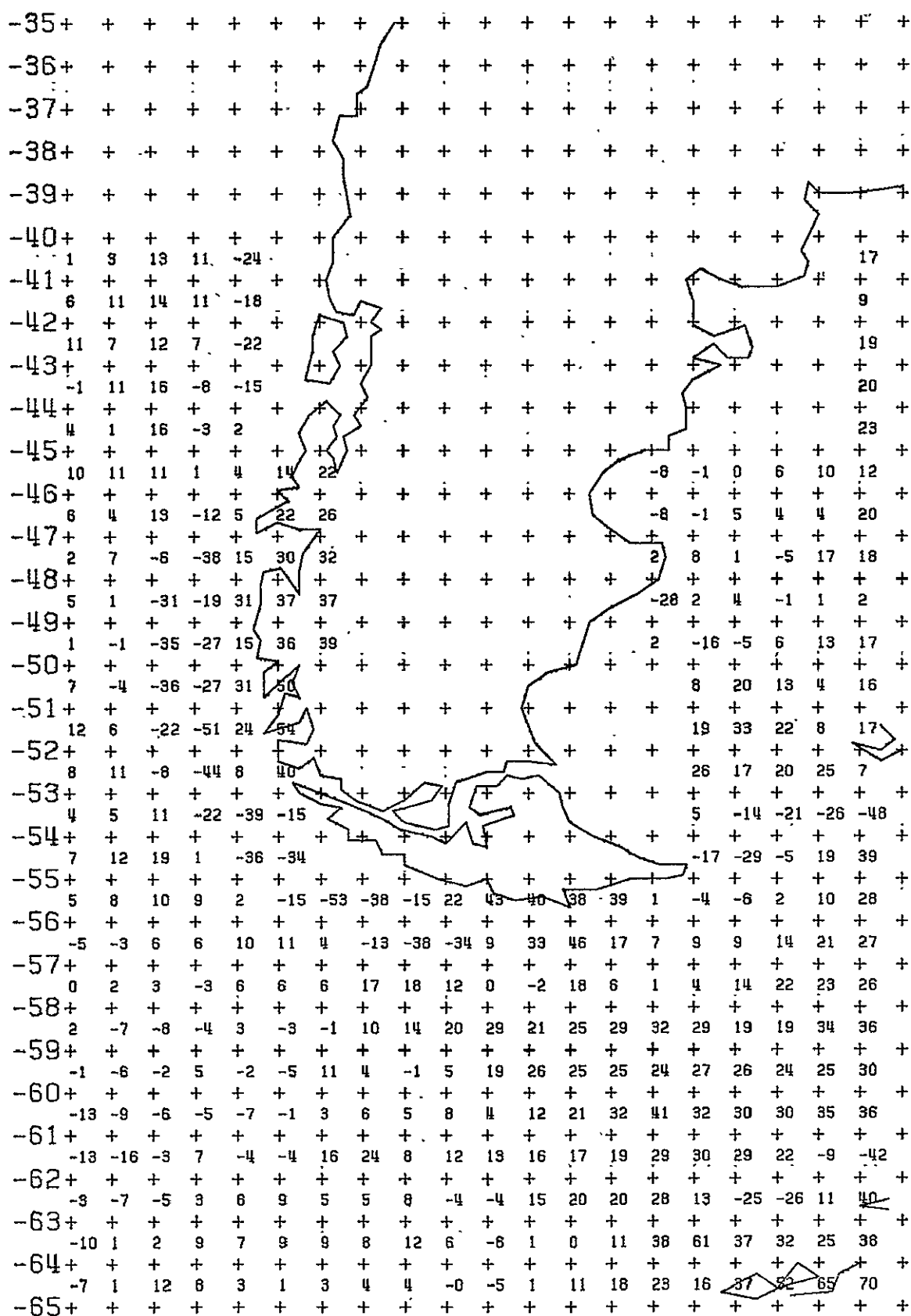
Figure B 23 B

-35+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-36+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-37+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-38+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-39+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-40+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-41+	+	+	+	+	+	+	+	+	+	+	+	+	10	7	8	7	8	7	6	7
-42+	+	+	+	+	+	+	+	+	+	+	+	+	6	12	9	7	6	6	8	7
-43+	+	+	+	+	+	+	+	+	+	+	+	+	11	7	7	6	6	7	8	8
-44+	+	+	+	+	+	+	+	+	+	+	+	+	9	8	6	7	8	7	7	7
-45+	+	+	+	+	+	+	+	+	+	+	+	+	9	7	7	8	9	8	7	7
-46+	+	+	+	+	8	9	8	8	7	8	8	7	7	7	8	8	7	7	7	6
-47+	+	+	+	+	11	7	7	8	10	7	6	6	7	8	8	7	7	6	7	8
-48+	+	+	+	+	10	8	8	8	8	7	7	7	9	6	8	8	8	7	9	7
-49+	+	+	+	+	9	12	9	7	6	6	8	8	7	8	7	7	9	8	8	7
-50+	+	+	+	+	12	9	8	8	7	8	7	8	8	7	7	9	9	9	8	8
-51+	+	+	+	+	12	10	7	7	7	8	9	7	7	8	7	8	8	7	7	8
-52+	+	+	+	+	9	8	7	6	9	8	7	7	8	8	9	8	8	7	6	7
-53+	+	+	+	+	9	7	8	8	7	7	7	6	9	9	9	8	8	9	9	8
-54+	+	+	+	+	7	9	8	7	8	7	7	9	10	8	9	9	9	9	7	8
-55+	+	+	+	+	9	8	8	8	8	10	8	12	9	9	8	7	8	8	9	9
-56+	+	+	+	+	10	10	9	8	8	8	8	10	9	8	6	6	7	6	7	7
-57+	+	+	+	+	8	8	8	9	13	12	10	8	8	7	7	7	8	6	8	7
-58+	+	+	+	+	8	10	9	10	10	9	8	9	8	8	8	8	7	8	8	8
-59+	+	+	+	+	10	11	10	8	8	8	8	10	10	10	9	9	9	9	8	9
-60+	+	+	+	+	9	7	7	8	8	10	9	9	8	10	9	10	11	10	8	8
-61+	+	+	+	+	9	9	8	10	8	12	9	11	8	11	10	9	9	9	11	8
-62+	+	+	+	+	10	9	8	10	9	11	7	9	9	9	8	10	10	9	10	10
-63+	+	+	+	+	9	9	10	9	10	10	10	10	8	10	7	6	9	8	9	8
-64+	+	+	+	+	9	10	9	10	8	10	8	10	8	8	8	8	9	8	8	8
-65+	+	+	+	+	10	9	9	9	8	9	8	10	9	9	10	8	9	8	9	9

260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 278 279 280

Accuracy of Predicted $1^{\circ} \times 1^{\circ}$ Mean Anomalies (mgals)

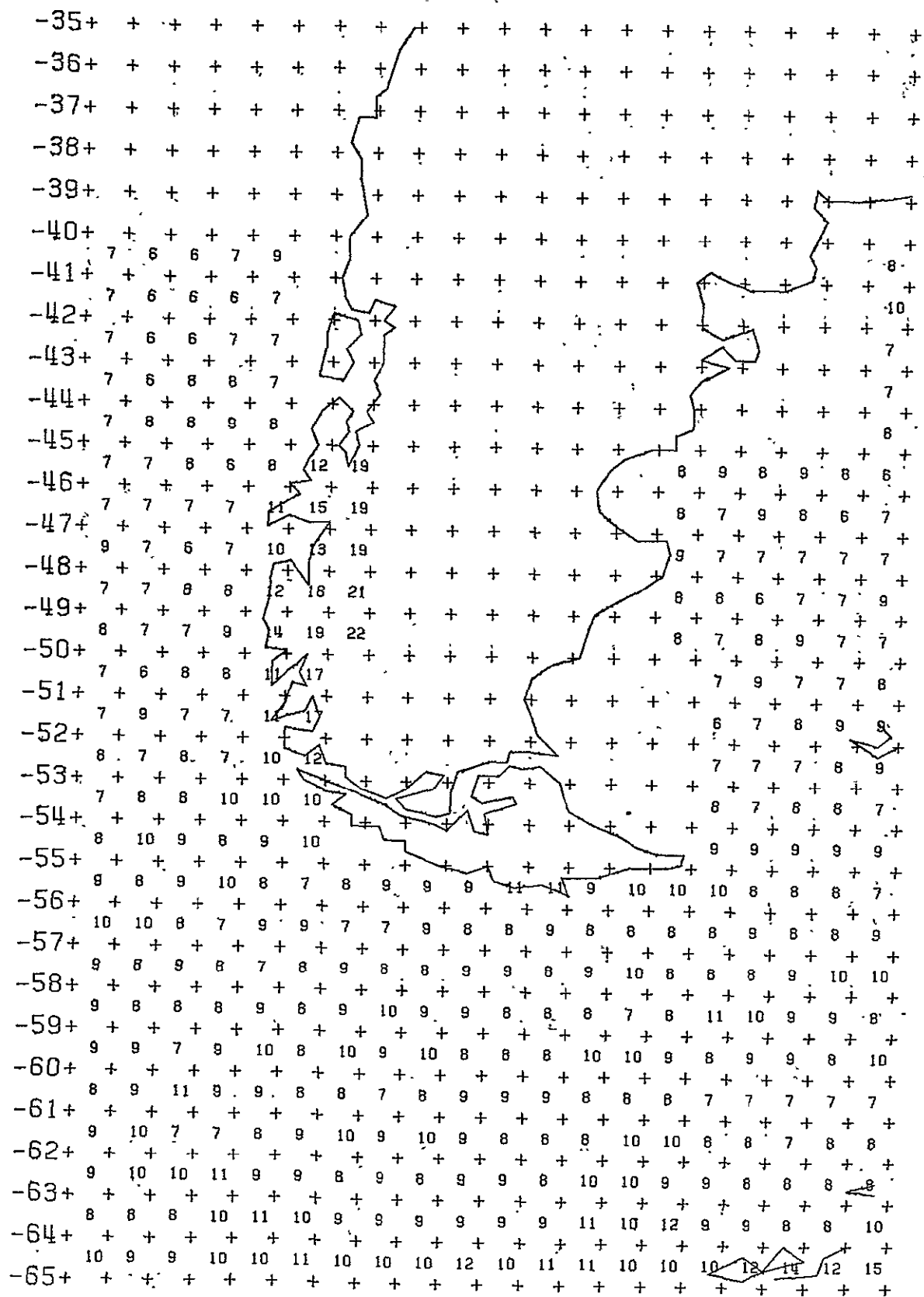
Figure B 24 A



280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300

1° x 1° Mean Free-Air Anomalies (mgals)

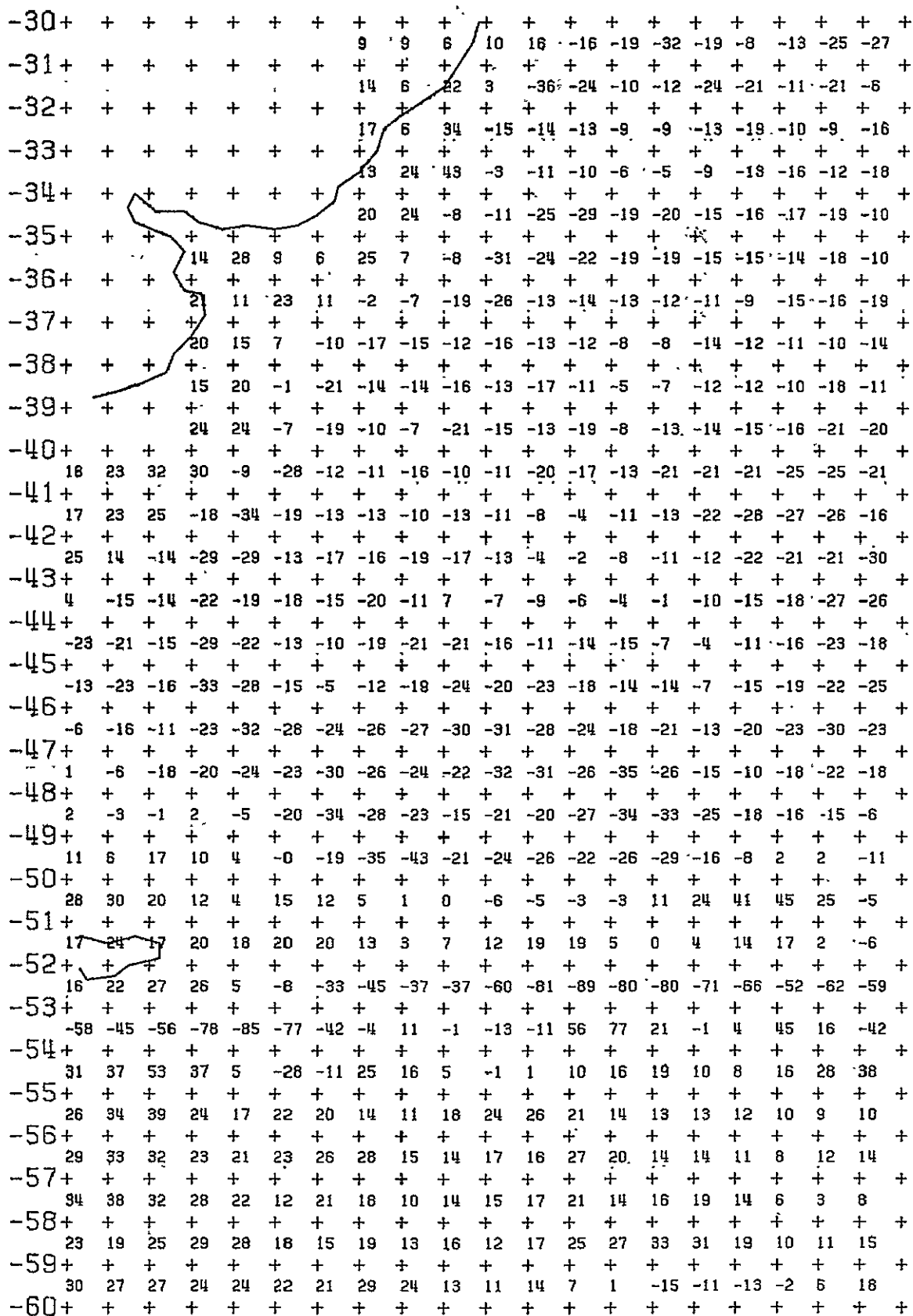
Figure B 24 B



280 281 282 283 284 285 286 287 288 289 290 291 292 293 294 295 296 297 298 299 300

.. Accuracy of Predicted 1°x1° Mean Anomalies (mgals)

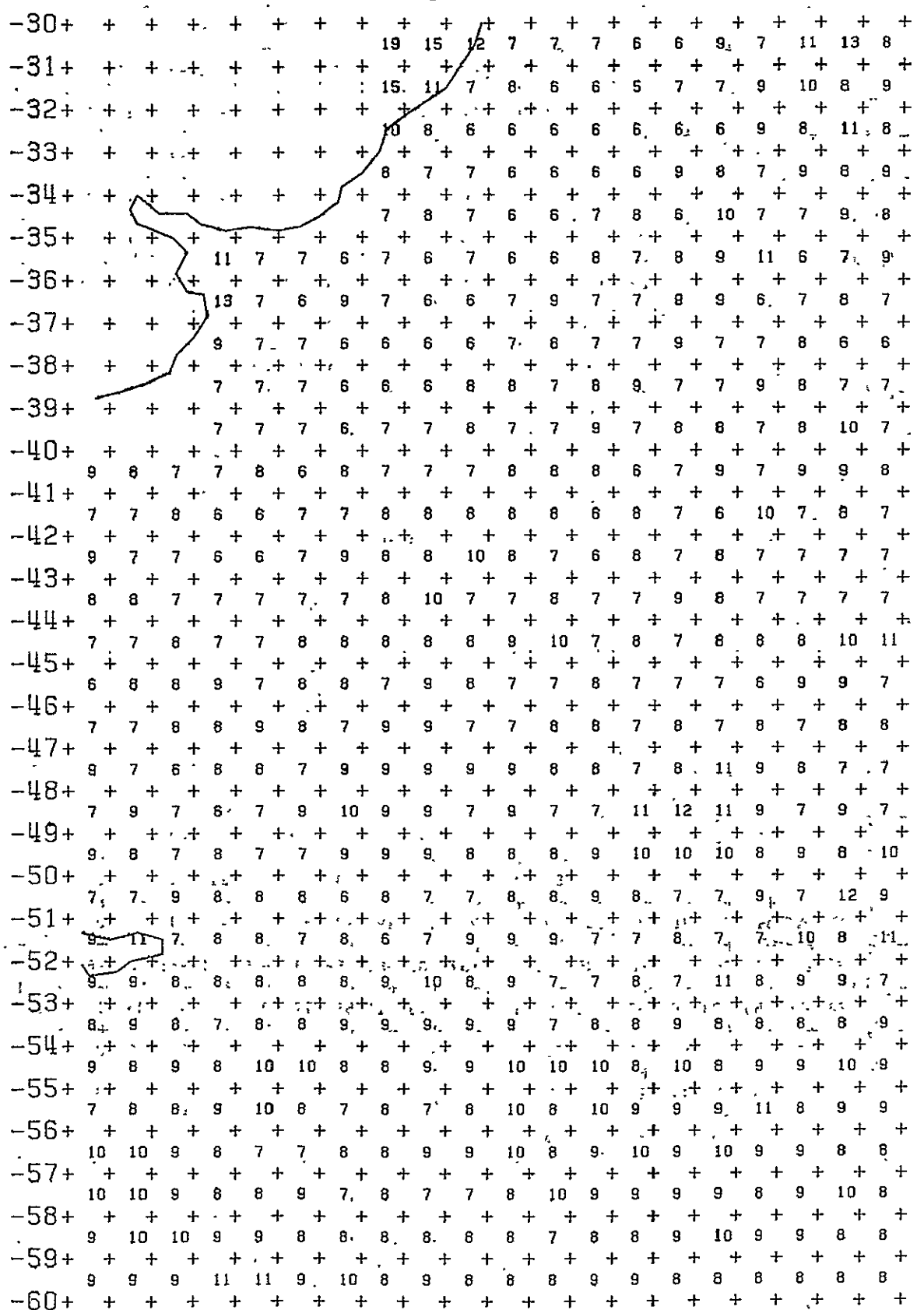
Figure B 25 A



300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320

1° x 1° Mean Free-Air Anomalies (mgals)

Figure B 25 B



300 301 302 303 304 305 306 307 308 309 310 311 312 313 314 315 316 317 318 319 320

Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

Figure B 26 A

-30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-19	-4	-3	21	29														
-31	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-18	-8	-14	-6	18														
-32	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-16	-13	-18	-1	1														
-33	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-17	-15	-15	-12	-11														
-34	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-16	-19	-16	-12	-2														
-35	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-13	-21																	
-36	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-16	-16																	
-37	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-15	-12																	
-38	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-16	-16																	
-39	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-15	-15																	
-40	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-14	-15	-14	-11	-9	-12													
-41	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-21	-17	-6	-13	-9	-5													
-42	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-22	-19	-18	-14	-16	-17													
-43	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-23	-32	-22	-15	-16	-17													
-44	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-18	-19	-21	-26	-18	-15													
-45	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-21	-16	-14	-16	-27	-24	-17	-18	-11	-4	-3								
-46	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-21	-23	-22	-26	-28	-27	-18	-13	-14	-8	-4								
-47	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-21	-23	-23	-16	-18	-16	-9	-12	-9	-5	0								
-48	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-11	-6	-6	-4	-11	-8	-7	-11	-6	-14	-12								
-49	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-29	-33	-29	-29	-18	-20	-16	-17	-18	-17	-15								
-50	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-12	-16	-12	-7	4	-3	-19	-9	0	2	-2	-9	-2	15	8	-2	-0	3	7
-51	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	3	2	8	15	-5	0	33	19	9	11	10	2	2	16	20	8	9	-1	2
-52	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-55	-50	-11	18	2	1	30	33	25	29	29	11	1	10	15	21	16	9	8
-53	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-59	-44	-11	2	-28	-24	14	32	33	37	25	18	17	6	0	13	22	20	8
-54	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	53	70	104	87	51	-3	-73	-83	-74	-68	-62	-79	-79	-43	14	-3	28	33	16
-55	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	3	-10	2	30	61	54	25	20	27	7	-3	3	-73	-125	-117	-5	46	42	26
-56	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	20	16	12	15	13	18	29	42	51	53	58	74	98	20	-137	-151	-9	32	25
-57	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	5	12	14	12	15	18	24	28	33	46	39	36	53	53	-19	-115	-56	22	27
-58	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	13	8	8	18	23	18	21	27	31	37	44	47	54	68	32	-56	-69	7	26
-59	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	22	14	7	8	25	20	20	29	31	35	41	42	36	21	-43	-113	-50	29	34
-60	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340

1°x 1° Mean Free-Air Anomalies (mgals).

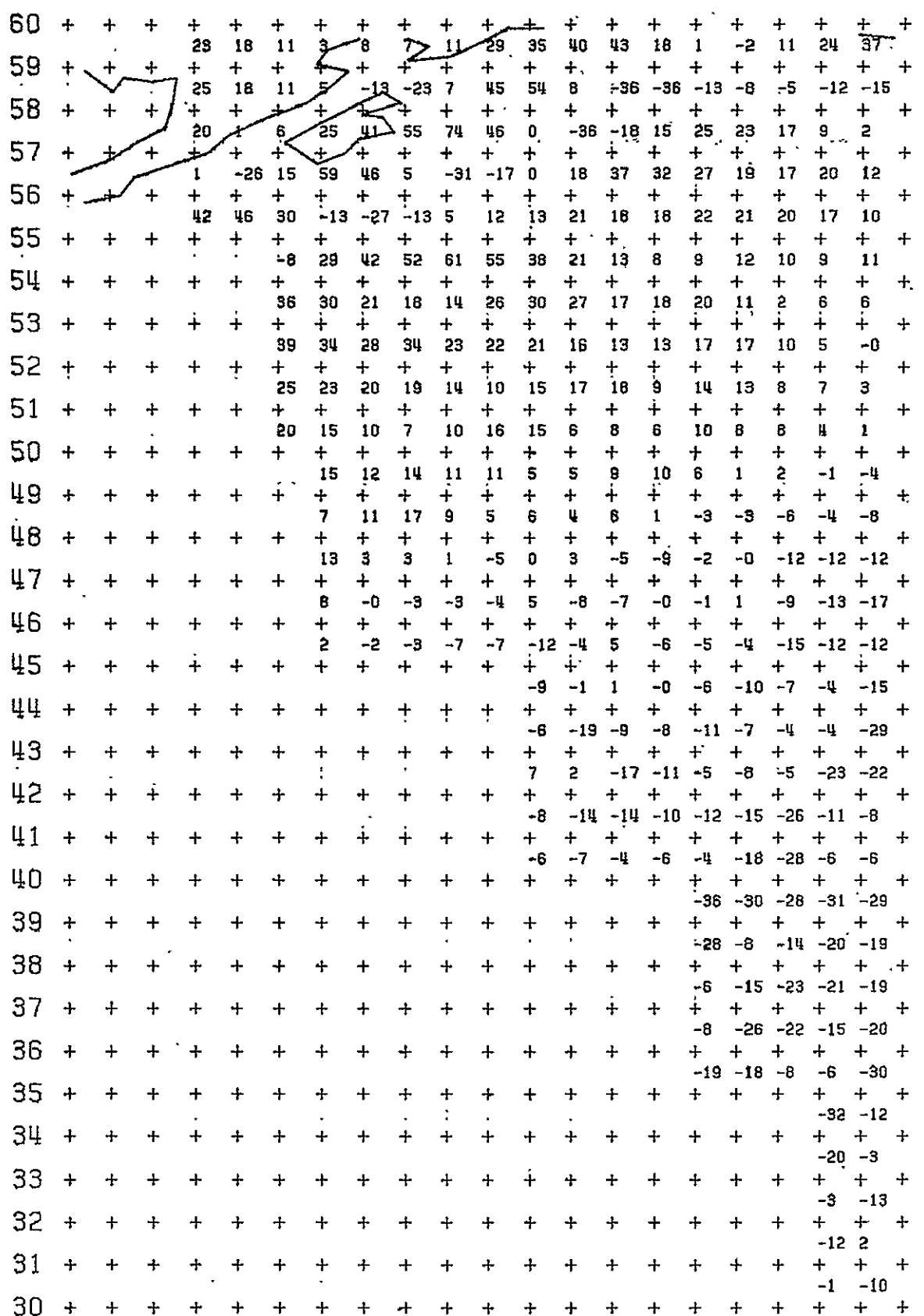
Figure B 26 B

-30+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
-31+	6	6	6	5	7														
-32+	6	7	7	6	6														
-33+	10	6	6	7	8														
-34+	9	8	8	8	6														
-35+	9	7	19	8	8														
-36+	7	12																	
-37+	9	9																	
-38+	7	7																	
-39+	7	6																	
-40+	7	7																	
-41+	7	6	7	11	8	10													
-42+	6	7	7	7	8	7													
-43+	10	9	8	7	6	8													
-44+	8	8	7	7	6	7													
-45+	7	8	8	8	7	8													
-46+	7	6	9	7	9	8	6	8	7	7	9								
-47+	7	8	6	8	10	8	8	6	6	7	10								
-48+	8	8	9	8	7	9	8	7	7	7	7								
-49+	7	8	8	8	8	7	7	10	9	7	8								
-50+	8	8	11	10	9	8	8	8	8	10	9								
-51+	8	8	6	8	8	9	8	10	8	8	11	10	8	8	7	9	9	12	10
-52+	10	7	8	7	7	9	9	9	9	9	8	9	8	8	7	7	7	9	8
-53+	9	11	10	8	9	7	7	8	10	10	8	8	7	9	8	8	6	7	10
-54+	8	8	11	9	9	8	9	8	7	8	9	8	7	8	8	8	9	8	7
-55+	9	9	8	11	12	12	9	10	7	8	7	8	8	8	8	8	8	7	8
-56+	7	8	9	9	8	8	10	10	9	7	7	6	8	10	10	8	7	8	9
-57+	10	10	8	9	9	8	7	8	7	8	9	9	8	8	7	6	9	9	7
-58+	8	8	8	9	8	9	7	8	8	8	9	8	9	8	7	8	7	10	9
-59+	8	8	7	8	8	9	8	8	9	8	9	9	10	10	9	10	10	9	8
-60+	8	8	8	9	9	10	9	9	10	12	12	11	12	10	8	9	10	9	8

320 321 322 323 324 325 326 327 328 329 330 331 332 333 334 335 336 337 338 339 340

Accuracy of Predicted 1°x1° Mean Anomalies (mgals)

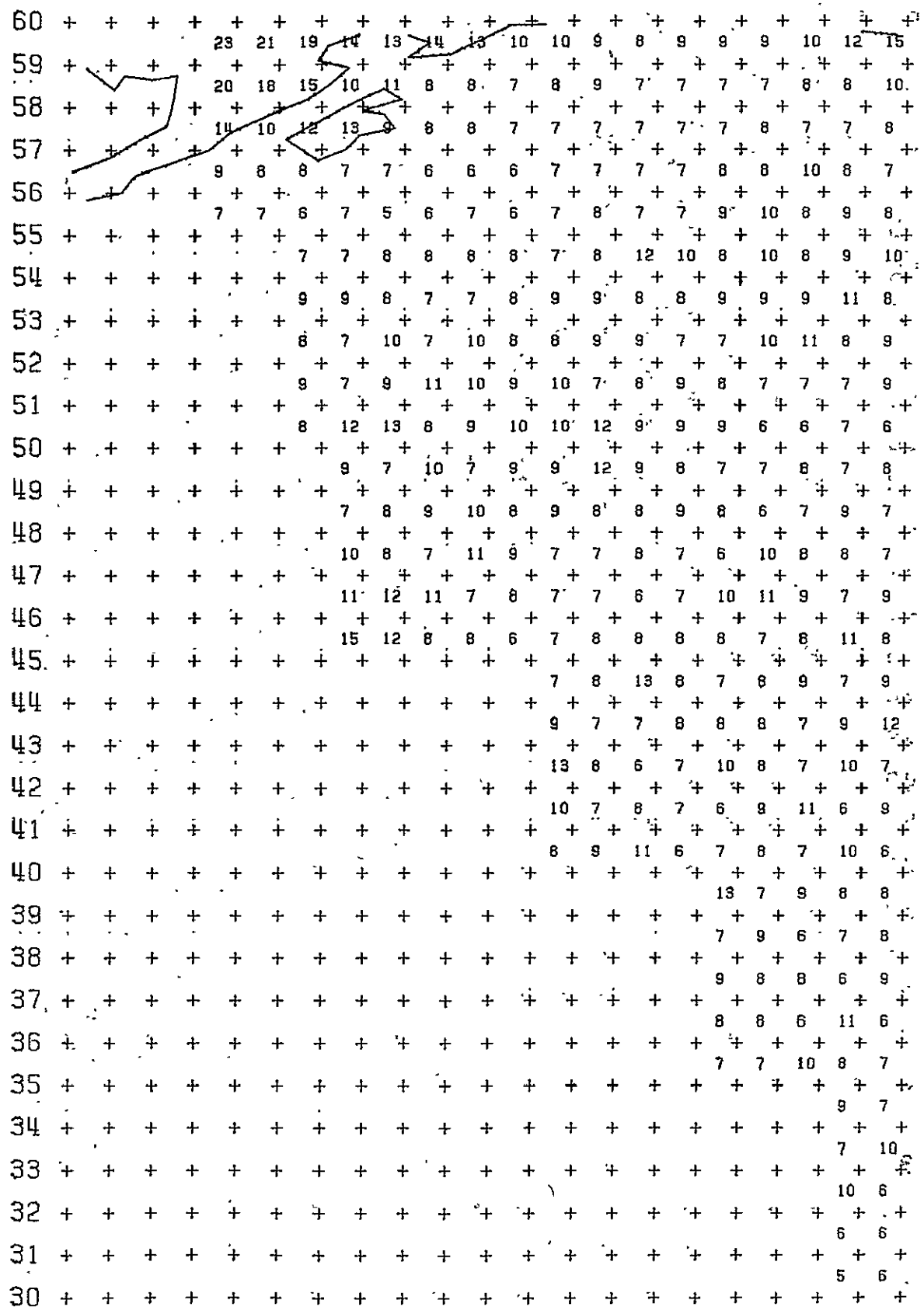
Figure B 27 A



200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220

1° x 1° Mean Free-Air Anomalies (mgals)

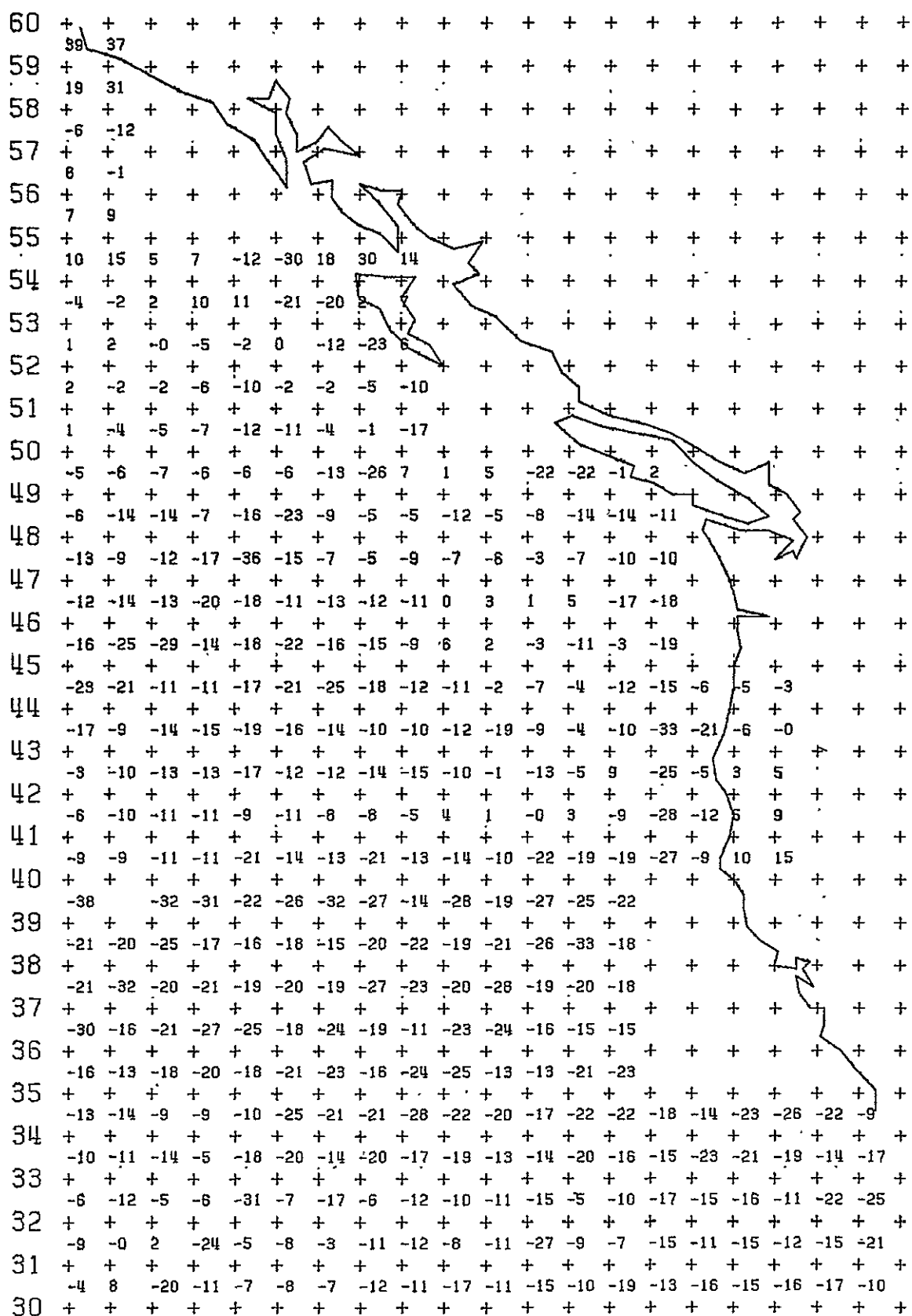
Figure B 27 B



200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220

Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

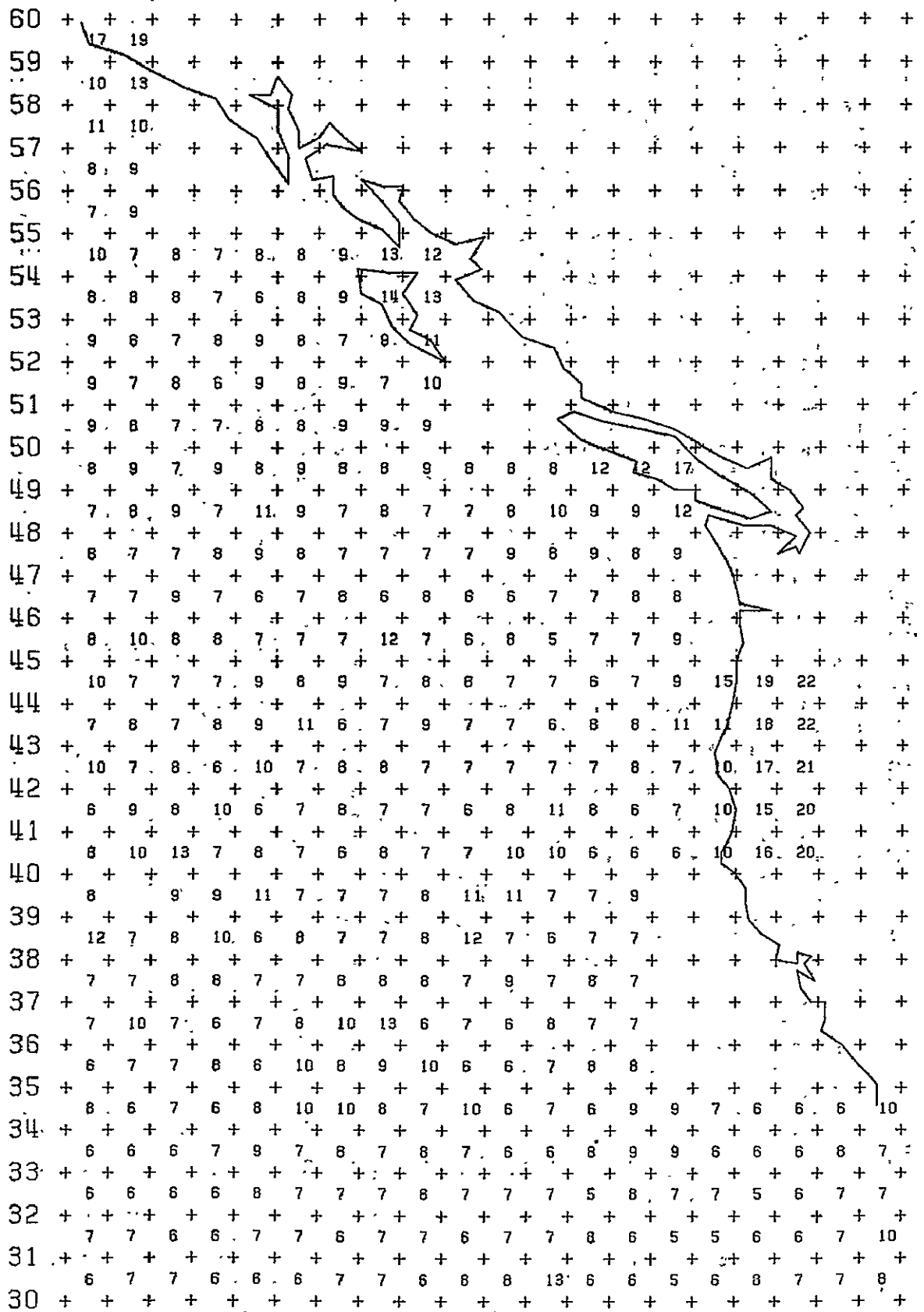
Figure B 28 A



1° x 1°. Mean Free-Air Anomalies (mgals)

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Figure B 28 B



Accuracy of Predicted 1° x 1° Mean Anomalies (mgals)

Figure B 29 A

30	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	2	-9	-21	6	-9	-7	-7	-7	-14	-18	-12	-14	-22	-16	-17	-21	-17	-16	-17	-12
29	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	2	-30	7	-13	-3	-9	-4	-7	-8	-14	-16	-22	-23	-18	-17	-11	-17	-17	-18	-17
28	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-16	-10	-6	-1	-7	-4	-12	-7	-19	-12	-14	-20	-19	-19	-18	-15	-20	-24	-17	-18
27	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-10	9	-4	-4	-3	-13	-9	-9	-13	-14	-18	-19	-17	-25	-18	-18	-18	-20	-15	-22
26	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	-4	-11	5	-0	-13	-6	-7	-21	-6	-29	-25	-16	-22	-19	-21	-22	-21	-19	-27	-22
25	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												-13	-16	-17	-10	-17	-24	-21	-25	-18
24	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												-10	-13	-18	-7	-18	-19	-23	-15	-26
23	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												-11	-10	-20	-19	-11	-19	-22	-22	-23
22	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												-16	-16	-21	-21	-16	-17	-27	-27	-20
21	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
												-19	-17	-23	-22	-20	-20	-24	-24	-19
20	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
																-24	-30	-15	-22	-22
19	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
																-19	-24	-22	-12	-26
18	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
																-27	-20	-14	-19	-22
17	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
																-22	-18	-22	-21	-10
16	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
																-17	-16	-17	-27	-25
15	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
14	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
13	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
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10	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
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8	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
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3	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
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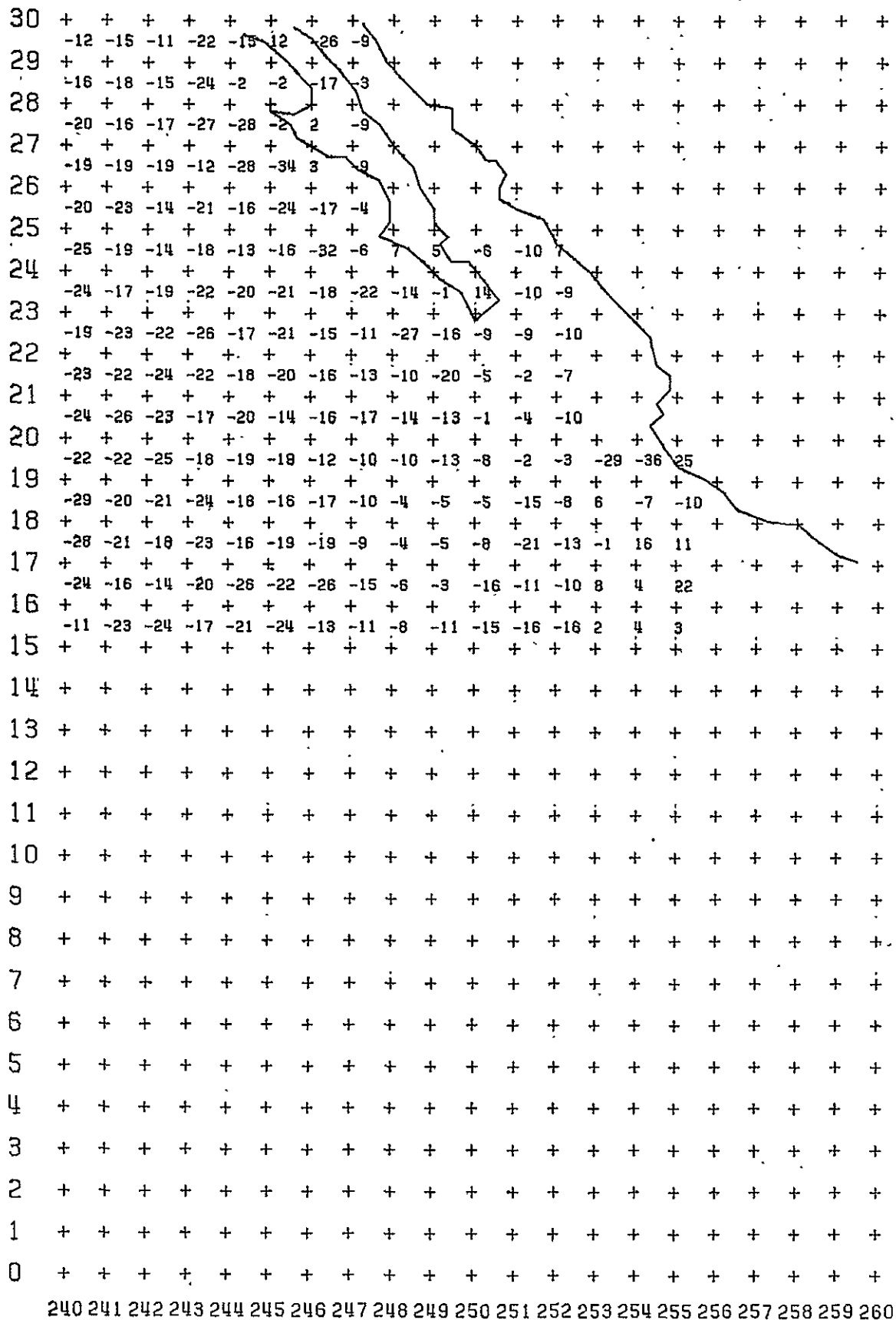
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1° x 1° Mean Free-Air Anomalies (mgals)

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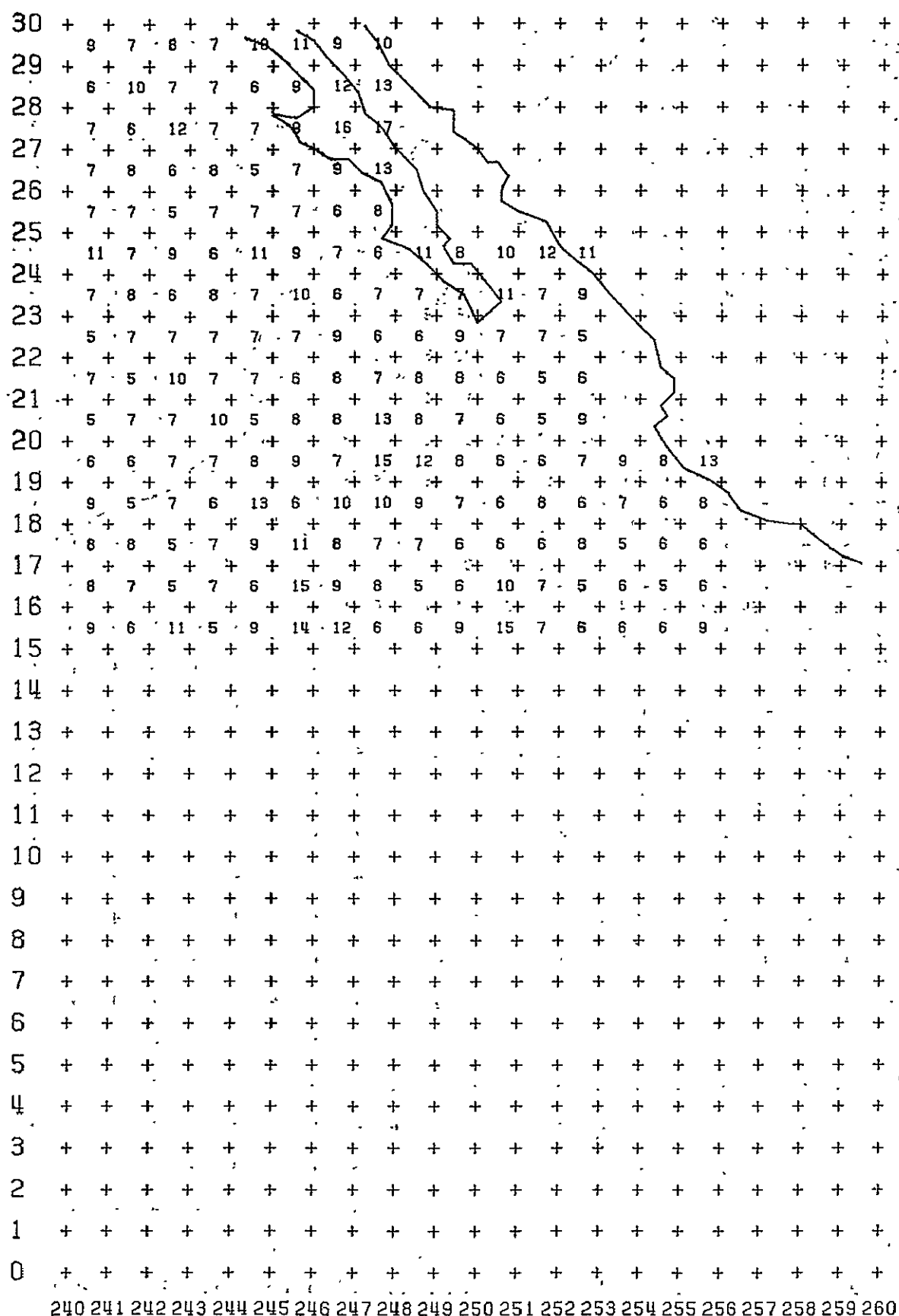
-110-

Figure B 30 A



1° x 1° Mean Free-Air Anomalies (mgals)

Figure B 30 B



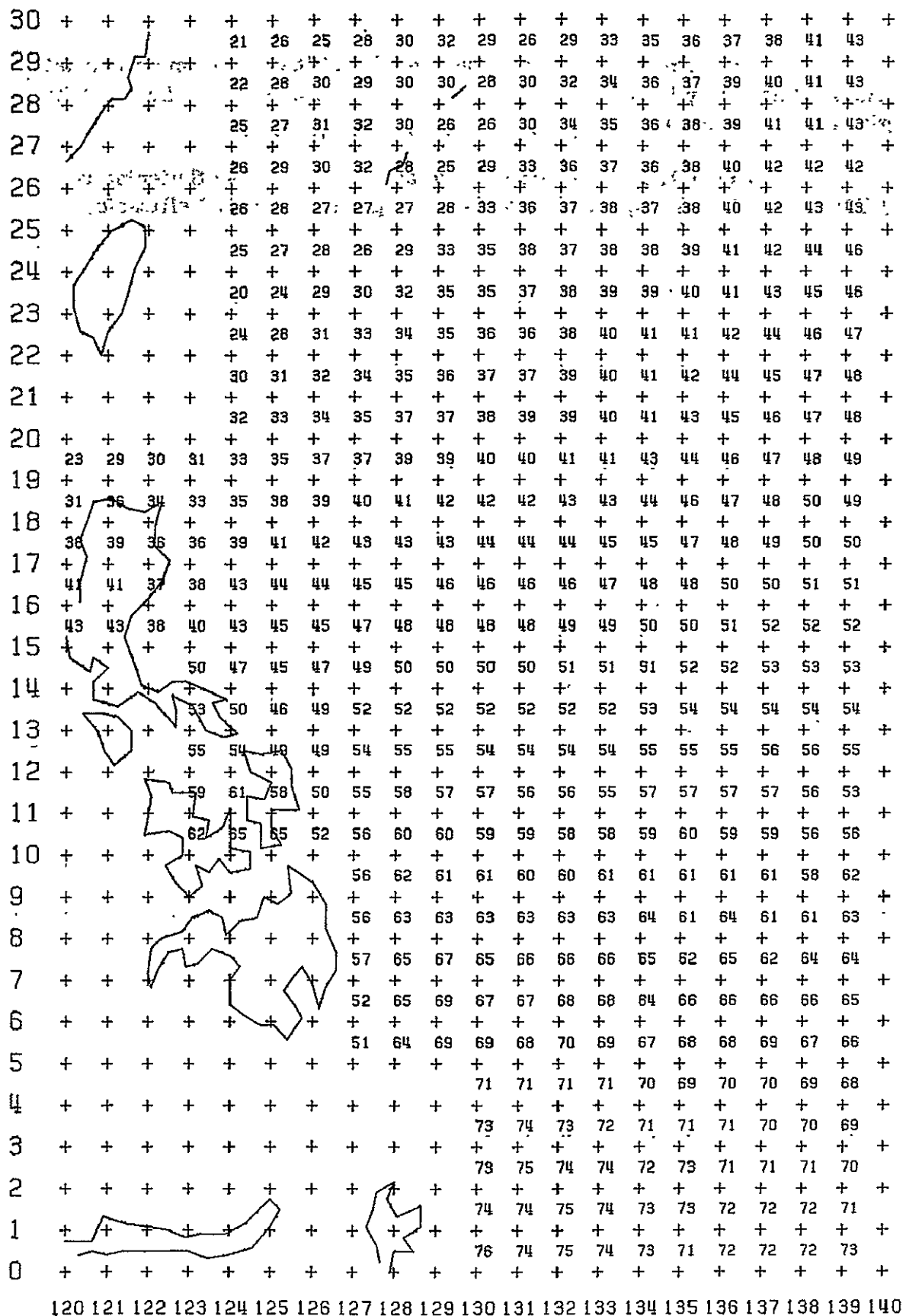
Accuracy of Predicted 1°x1° Mean Anomalies (mgals)

Appendix C

This appendix contains a sample plot of the $1^\circ \times 1^\circ$ mean undulations and their accuracy for one geographic region (Block 3 shown in the index map given in Appendix B).

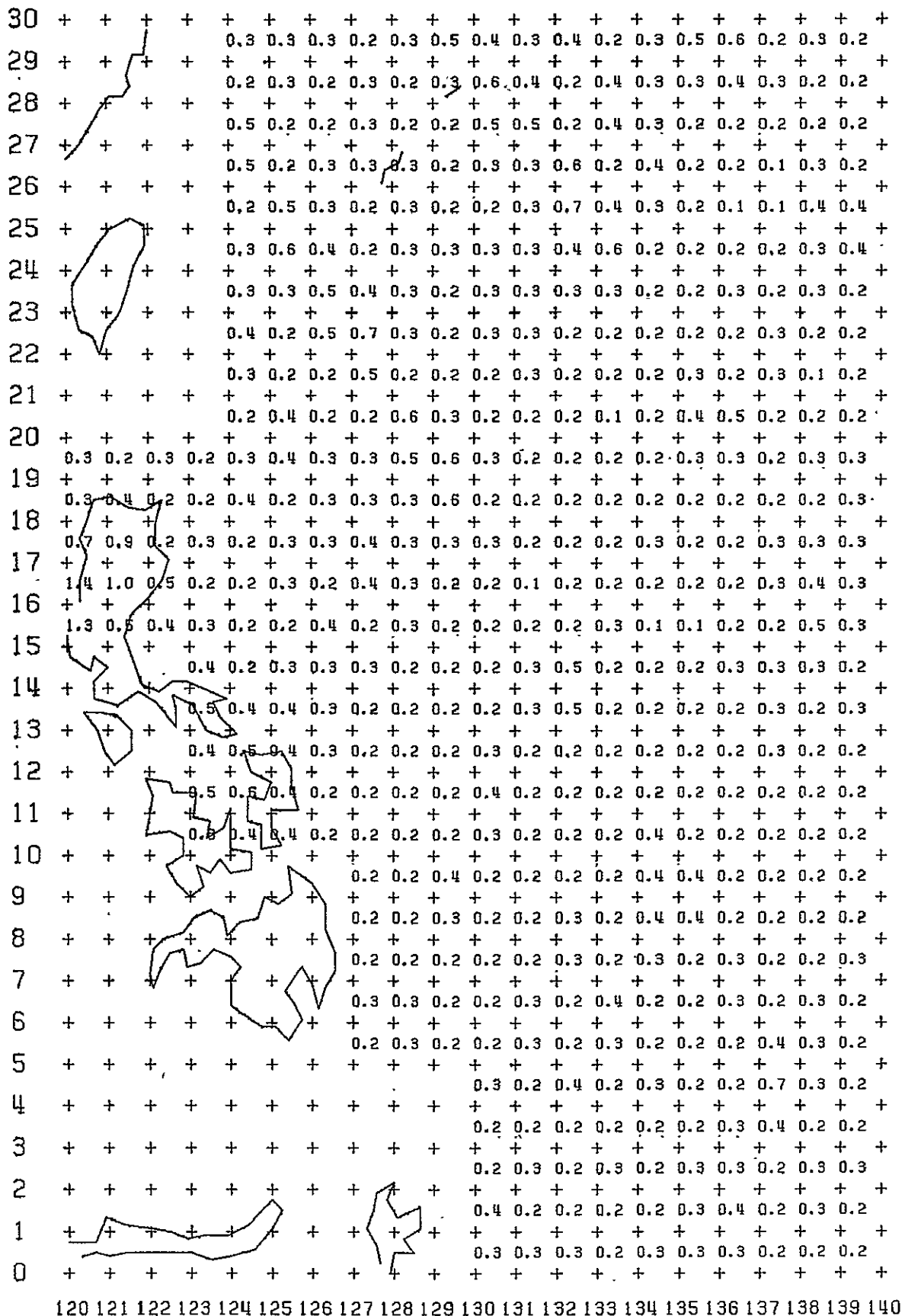
The undulations given refer to an ellipsoid whose flattening is $1/298.257$ and whose equatorial radius of the given terrestrial ellipsoid.

Figure C 1



1° x 1° Mean Geoid Undulations (meters)

Figure C 2



1° x 1° Mean Undulation Accuracies (meters)

1. Report No. NASA CR-156843	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Mean Gravity Anomalies and Sea Surface Heights Derived from GEOS-3 Altimeter Data		5. Report Date October 1978	
		6. Performing Organization Code	
7. Author(s) Richard H. Rapp		8. Performing Organization Report No.	
		10. Work Unit No.	
9. Performing Organization Name and Address Ohio State University Research Foundation 1958 Neil Avenue Columbus, OH 43212		11. Contract or Grant No. NAS6-2484	
		13. Type of Report and Period Covered Final Report	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Wallops Flight Center Wallops Island, VA 23337		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract Approximately 2000 GEOS-3 altimeter arcs, supplied by the NASA Wallops Flight Center and received by September 1977, have been analyzed to improve our knowledge of the geoid and gravity field. The first step in this process was a complex editing procedure used to eliminate bad and unacceptable data. After this, an adjustment procedure was used to fit the sea surface heights (geoid undulations) implied by the altimeter data to the geoid undulations implied by the GEM 9 potential coefficients, in an adjustment process that incorporated cross-over constraints. The error model used for the fit was a one or two parameter model which was designed to remove altimeter bias and orbit error. The adjustment process was carried out in two stages: first in a primary net of global data in 854 arcs; second in six regional areas. Typical a priori cross-over discrepancies were ± 8 meters while a posteriori discrepancies were on the order of ± 0.6 meters. The undulations on the adjusted arcs were used to produce geoid maps in 20 regions where the data was suitably dense. In addition, the adjusted data was used to derive $301\ 5^\circ$ equal area anomalies and $9995\ 1^\circ \times 1^\circ$ anomalies in areas where the altimeter data was most dense, using least squares collocation techniques. The average predicted accuracy of the 5° anomalies was ± 3 mgals, and ± 6 mgals for the $1^\circ \times 1^\circ$ values. Comparisons with terrestrial data indicate these anomaly accuracies were reasonable. We also emphasized the ability of the altimeter data to imply rapid anomaly changes of up to 240 mgals in adjacent $1^\circ \times 1^\circ$ blocks.			
17. Key Words (Suggested by Author(s)) geoid GEOS-3 gravity anomalies altimetry		18. Distribution Statement Unclassified - unlimited STAR Category - 42,46,48	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 119	22. Price*